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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXVII.—*On the Geology of Southern Patagonia;* by J. B. Hatcher.

It is the purpose of this paper to record such facts relating to the geology of southern Patagonia as were observed by the author during his explorations in that country from May 1st, 1896 to June 5th, 1897, while collecting vertebrate fossils for Princeton University; to offer a few suggestions as to the age and origin of the different sedimentary deposits and their stratigraphic relations to one another as displayed by sections in different parts of the region; and to make some remarks in regard to the agencies which have determined the present topographical features of the district visited.

Partly in order to assist others who may visit this country for the purpose of collecting fossils, but more especially for the purpose of facilitating the work of future investigators who may desire either to verify or disprove the correctness of my observations, I present here a sketch map of the Argentine territory of Santa Cruz (see p. 347), on which I have designated the most promising localities for vertebrate fossils observed by myself and my assistant, Mr. O. A. Peterson; and those places at which the stratigraphical sections accompanying this paper were made. It is believed that with the aid of this map it will be readily possible for anyone to identify all the more important localities mentioned in the text.

While my observations and conclusions are in many in-

stances quite different from, and in a few cases directly opposed to those of Dr. Florentino Ameghino and his brother Carlos Ameghino; yet it is believed that most of the conclusions reached are fully warranted by the facts observed; and that in the present paper there will be found an important supplement to our knowledge of this region, which has already been so much increased by the combined efforts of the brothers Ameghino.

Mesozoic Rocks.

Jurassic?—The oldest sedimentary deposits seen by the writer were a series of black, very hard, but much fractured slates, with Ammonites fairly abundant, but not sufficiently well-preserved to admit of identification. These beds, which I propose to call the *Mayer River beds*, in some places at least, rest directly on the eruptive rocks which here form the great mass of the Cordilleras; they are well represented on the right bank of the lower fork of Mayer River, just where it emerges from a deep gorge about three miles above its confluence with the main stream.* A greater development of these beds may be seen at the west end of Bald Mountain, an elevation in the middle of Mayer Basin; at this locality they have a decided eastwardly dip and an estimated thickness of 1500 feet. In their uppermost layers, they are sometimes of a red or yellow color and are less fractured and more cleavable than on Mayer River. No fossils were found on Bald Mountain.

The Mayer River beds are referred to the Jurassic, partly because of the Ammonites found in them, which appear to resemble Jurassic forms; but more especially on account of their lithological characters and because of the great thickness of the sedimentary rocks overlying them, which, by the presence of Dinosaurian remains in their uppermost strata, can hardly be more recent than Cretaceous.

Cretaceous.—Immediately, but unconformably, overlying the Mayer River beds, is a series of heavily bedded, light brown sandstones, becoming variegated above, exceedingly barren of fossils and with an estimated thickness of 1000 feet. In their lower layers they resemble in appearance the Dakota sandstones of our western States. They are well represented near the source of Mayer River, where they extend for several miles in an unbroken wall, forming the southern border of Mayer basin. With the exception of uncharacteristic plant impressions no fossils were found in these sandstones. They are referred to the Cretaceous upon stratigraphical evidences

* Many of the water courses and topographic features mentioned in this paper will not be found located on any of the current maps of Patagonia. For reference they have been located and given names on the accompanying map.

and are supposed to represent the variegated sandstones (*Areniscas abigarradas*) of Carlos Ameghino;* although both in this region, and on the upper Rio Chalia they appear to be unconformable with the overlying Dinosaur beds.

The Guaranitic beds.—Above the barren sandstones there is a series of variously colored sandstones and clays of immense thickness, not less than 2000 feet, and in which there occur in the greatest profusion the mineralized trunks of trees and, less frequently, Dinosaurian remains. Dr. Ameghino† has already called these beds the *Guaranitica beds* and referred them to the Upper Cretaceous upon the evidence afforded by the Dinosaurs found in them. The Guaranitic beds are well represented on the head of Lignite creek on the south side of Mayer basin, and on the upper Rio Chalia; in both of these localities they are much tilted and have a general dip to the southeast.

The Pyrotherium beds.—I mention here the Pyrotherium beds and place them in the Cretaceous entirely upon the authority of Ameghino. In my work on the Upper Rios Chalia and Chico I was unable anywhere to identify the Pyrotherium beds or to find evidences of the rich mammalian fauna found in them by Carlos Ameghino. According to Dr. Ameghino these beds immediately overlie the Dinosaur beds and pass insensibly into them.‡ No difficulty whatever was experienced in determining the Guaranitic beds and in finding Dinosaurian remains in them. I searched faithfully these Dinosaur beds from the base of the marine Tertiary above to the barren sandstones below for mammal remains, but *without the slightest success.* I never found in position in the Dinosaur beds a single mammal bone or tooth. I did find mammal remains in this region which seem to pertain to the genus Pyrotherium, but they belong to a horizon much more recent than the Guaranitic beds or even the Patagonian beds, and should not be placed lower in the geological scale than Miocene, for they are above the Supra-Patagonian beds of Ameghino. I present here in fig. 1 an incisor tooth, No. 15101 in our collection, which from its size and shape appears to agree pretty closely with the incisors of Pyrotherium. Only part of that portion projecting from the jaw is preserved and this is nine inches in length and nearly three inches in greatest diameter.

* See "Note on Geol. and Pal. of Argentina," Geol. Mag., Jan., 1897, p. 5, and Bol. Inst. Geografica Argentina, vol. xvii, 1896. pp. 87–108, and C. Ameghino, "Expl. Geol. en la Patagonia," Bol. Inst. Geografica Argentina, vol. xi, 1890, pp. 1–46.

† See F. Ameghino, "La Argentina al Traves de las Ultimas Epocas Geologicas; Imprenta de pabla E Coni e Hijos, Buenos Aires, 1897, p. 33.

‡ F. Ameghino, Note on Geol. and Pal. of Argentina, Geol. Mag., London, January, 1897, pp. 4–20.

It was found associated with the remains of other mammals, birds and small reptiles. From the stratigraphic position of the beds in which this tooth and the associated fossils were

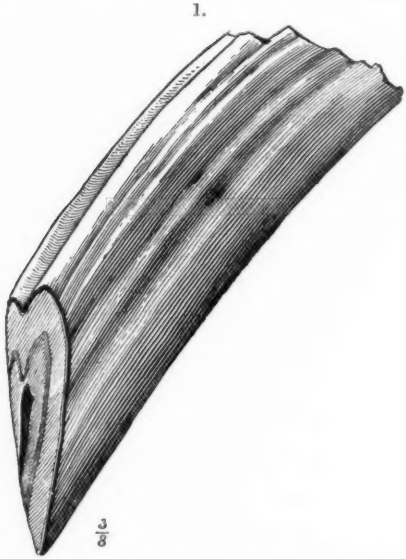

FIG. 1, right sup. incisor of Pyrotherium? three-eighths natural size.

found I did not suspect that they were in any way related to the Pyrotherium beds and spent very little time in them.

I seriously question the stratigraphic position of the Pyrotherium beds as determined by the brothers Ameghino, although it may seem presumptuous on my part, since I was unable to identify the beds at all, and the explorations, travels and opportunities for observations in this region of Señor Carlos Ameghino have been far more extensive than have my own. It is certainly remarkable that in these beds containing Dinosaurian remains, associated according to Ameghino with the remains of mammals, some of them, as for example Pyrotherium of *immense* size, only a little less than that of the elephant and consequently easily to be seen, I could have searched for weeks without ever finding a single mammalian bone, while every day I found Dinosaurian remains.

Considering the immense size and highly specialized character of many, in fact of most of the mammals described by Ameghino from the Pyrotherium beds, it does not seem possible that they could have lived in Cretaceous times and coex-

isted with the Dinosaurs of that period. From a study of the figures and descriptions published by Dr. Ameghino of the fossils found in the Pyrotherium beds, one is even led to believe that they may belong to a period more recent than that of the Santa Cruz beds. I present here in fig. 2, taken from one of Ameghino's latest publications, the superior dentition of *Morphippus imbricatus*, one of the smaller ungulates described by him as coming from the Cretaceous of Patagonia.

2.

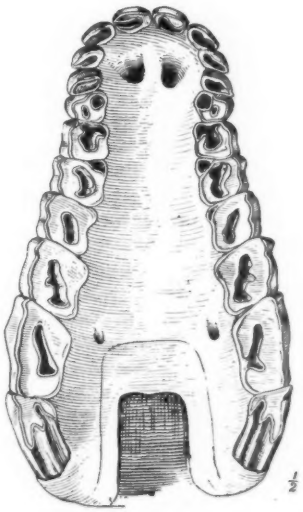

FIG. 2. Sup. dentition of *Morphippus imbricatus* Amegh., after Ameghino. One-half nat. size.

The entirely molariform condition of the premolars and the cupped incisors are especially noteworthy. In his "Notes on the Geology and Paleontology of Argentina" previously referred to, he says on page 8, in speaking of the Pyrotherium fauna, "The unarmored edentates are also numerous and of types resembling those of the Santa Cruz formation, but generally of much more considerable size. Nevertheless some forms show very primitive characters, having the molars provided with a well developed layer of enamel.

"With these edentates there are Carnivorous animals of a size approximating to that of the largest bears of the present day, but similar to those of the Santa Cruz formation." This is certainly a greater size than that attained by any of the Carnivorous animals of the Santa Cruz beds. Moreover many of

the ungulates described by Ameghino as from the Pyrotherium beds are larger than the allied forms in the Santa Cruz beds. Now as regards structure and specialization of parts we are as yet unable to judge in many cases just which forms are the more specialized. In not a few instances, in his descriptions of remains from the Pyrotherium beds, he shows that they are not distinguished either generically or specifically from allied forms in the Santa Cruz beds, sometimes that they are decidedly more specialized than the latter, and almost always that they are of a size and structure showing a close relation with the fauna of the Santa Cruz beds and not at all what we should expect from the Cretaceous. As instances of this I may cite that in his "Première Contribution à la Connaissance de la faune Mammalogique des Couches à Pyrotherium" on page 44, in closing his description of *Asmodeus Osborni* he remarks, "Cet animal est assurément un des plus gros mammifères qui ait foulé la surface de la terre." Again on page 50 in defining the genus *Ancylocœlus*, he compares it with *Homalodontotherium*, a closely allied genus from the Santa Cruz beds but which is distinguished from the latter partly by the dental formula, which he finds to be $I\frac{3}{3}C\frac{1}{1}P\frac{4}{4}M\frac{3}{3}$ in *Homalodontotherium*, while in Ancylocœlus from the Pyrotherium beds there is a reduction in the number of inferior premolars to three on either side, a marked advance over the Santa Cruz form. On page 56 he mentions edentates from these beds of the stature of Mylodon. Many other similar examples might be cited, but enough has been done to show that we are not dealing with a Cretaceous fauna. Thus, from his own figures and descriptions it would appear that in the matter of size at least, there is a *decided* advantage in favor of forms found in the Pyrotherium beds as compared with related forms from the Santa Cruz beds. In the history of the development of every mammalian phylum in the northern hemisphere, so far as I am aware, there is a decided and gradual increase in the size of the individual from the lower to the higher forms. According to Dr. Ameghino, exactly the opposite has taken place in South America. It would be interesting to know why it is that natural causes always working by the same methods have produced such opposite results in the two hemispheres, when as is everywhere shown, especially among the ungulates there are such marked cases of parallelism in structural development.

Whatever may be the relation of the Pyrotherium beds to the Santa Cruz beds, I feel sure that the mammalian fauna described by Florentino Ameghino as from the Pyrotherium beds does not occur associated with the Dinosaurian remains of the Guaranitic beds, unless such association is due to secondary deposition of the latter or a superficial mingling of

remains from two or more distinct horizons by recent erosion; which latter has been the cause of much confusion in other instances, as for example, the Loup Fork and Equus beds of our western plains.

Dr. Ameghino,* in giving his reasons for referring the Pyrotherium beds to the Cretaceous, says: "I rely on the fact that these beds with remains of Pyrotherium everywhere accompany the red sandstones with remains of Dinosaurs, so that it has not hitherto been possible to separate them in an absolute manner. These sandstones in certain places exhibit nothing but bones of Dinosaurs; in others they show only remains of mammals and small reptiles of types not yet determined, while at other points all these remains are shown mixed together, at least to *all appearance* (italics mine), always accompanied by a great quantity of silicified wood." Now according to Ameghino's own statements, in the localities where this Pyrotherium fauna has been found most abundantly, the nature of the country is just such as to bring about a mingling of remains really belonging to quite different horizons, and thus their association in the same horizon may be only *apparent*, as he himself has in reality suggested. In another publication† he says: "Malheureusement ce nouveau gisement se trouvait dans une région absolument inconnue et accidentèe d'une manière épouvantable; il s'égara au milieu de ce labyrinthe et ne put en sortir qu'à dure peine en abandonant une partie du matériel de voyage." I may also add that in the region of Mayer basin and the upper Rio Chalia, especially the former, there have been great disturbances, so that the Guaranitic beds and the superimposed Tertiary deposits are inclined at high angles. In such a region the exact stratigraphic relations of the different beds are not always easily determined, and in some cases grave errors have arisen through false determinations made by most capable men. As an example of this, it need only be remembered that Señor Carlos Ameghino spent five years in Patagonia, working mostly in the Santa Cruz beds, before discovering that they overlie the Patagonian beds,‡ all the while considering them as below the latter series (although Darwin had fifty years before suggested the true conditions),§ and this far out from the mountains and in a region singularly free from faults or dislocations of any kind, where the strata are approximately horizontal and succeed one another in regular order.

* Loc. cit.

† See Prémière Contribution à la Connaissance de la Faune Mammalogique des Couches à Pyrotherium. Florentino Ameghino, Bol. del Inst. Geo. Arg., tome xv, cahiers 11 et 12.

‡ See Énumération Synoptique des Espèces de Mammifères Fossiles des Formations Éocènes de Patagonie, par Florentino Ameghino. Buenos Aires 1894, pp. 1–8.

§ See Geol. Observ. on South America, p. 117.

It is true that Dr. Florentino Ameghino states that the variegated sandstones of the interior extend to the Atlantic coast, and are covered in concordant stratification by the same strata with *Pyrotherium;* but since he gives no localities and nowhere describes any remains of Pyrotherium or other mammals from those beds as having been found at San Julian or other localities on the coast, the correct identification of those beds as Pyrotherium may well be questioned.

I have dwelt at some length upon the question of the age of the Pyrotherium beds because of the importance of the problems involved. If the beds containing this remarkable mammalian fauna be really Cretaceous, not only may the value of vertebrate fossils as means of correlation be seriously questioned, but a very decided blow will also be struck at the validity of all correlations based on paleontological evidences, whether of vertebrates, invertebrates or plants.

Until this entire region has been carefully explored and the stratigraphic position of the Pyrotherium beds accurately determined, by men trained in stratigraphic work, the question of their exact position in relation to the Dinosaur beds and to the different Tertiary beds, as well, will remain unsettled in the minds of most vertebrate paleontologists.

Tertiary Deposits—Eocene.

The Patagonian beds.—Extending along the Atlantic coast in an almost unbroken succession from New Bay on the north to near the mouth of the Coy River on the south, there is a series of light-colored, well stratified sandstones and clays, usually quite soft but sometimes, especially in the sandstone layers, enclosing very hard, lenticular concretions. These beds are known as the Patagonian beds, and the typical locality for them may be considered as the Atlantic coast anywhere from Port Desire to the mouth of the Santa Cruz River. They attain to a thickness of several hundred feet, are of marine origin and are everywhere characterized by marine invertebrates in great abundance. In the region south of Port Desire they dip very gradually to the southeastward, so that their uppermost strata disappear beneath the waters of the Atlantic about midway between the Santa Cruz and Coy Rivers.

In regard to the age of the Patagonian beds there has been great difference of opinion, but most persons acquainted with them and with the invertebrate fauna found in them agree in referring them to the Eocene. Dr. Ameghino, in discussing this question, says:* "The fact is that the Patagonian formation begins with the Upper Cretaceous, but acquires its great-

* See Notes on Geol. and Pal. of Arg, p. 12.

est development during the Eocene. The fossiliferous deposits of Quiriquina were at first regarded as Tertiary, and were only assigned to the Cretaceous after there had been discovered in them remains of *Plesiosaurus* (*Cimoliosaurus*) *chilensis*, of *Ammonites*, and some other Secondary genera.

"The late Cretaceous formation of the coast of Chili exhibits absolutely the same aspect and the same lithological characters as the Patagonian formation. The facies of the fauna is equally the same, since the Cretaceous fauna of Quiriquina only differs from the fauna of the Patagonian formation by the presence of eight genera (*Ammonites*, *Hamites*, *Baculites*, *Pugnellus*, *Cinulia*, *Pholadomya*, *Monopleura*, *Trigonia*), which are not met with in this latter; while 85 per cent, more or less, of the genera of the Cretaceous formation are also found in the Eocene Patagonian formation. Moreover according to Philippi, the best authority on the subject, 20 per cent of the species of shells of the Cretaceous formation of Algarroba are likewise species of the Patagonian formation, and it will be recognized that in Patagonia the marine Cretaceous and Eocene formations pass from one to the other in a gradual and insensible manner."

Granting that the facts as stated above are correct, and Dr. W. Moericke* has shown that considerable doubt exists as to the above association of species at the localities mentioned, they do not justify Dr. Ameghino's conclusion that the Lower Patagonian beds belong to the Upper Cretaceous; for in regard to the eight genera mentioned above as found only in the Cretaceous of the west coast and not in the Patagonian beds, it should be remembered that of these, six are characteristic of the Mesozoic, and are unknown in any deposit later than Cretaceous, while the two remaining, *Pholadomya and Trigonia*, are found indiscriminately from the Lias to recent times. The per cent of genera or even of species common to the two deposits is of less importance than the character of the genera and species peculiar to each. Now six of the eight genera found in the Cretaceous deposits of the west coast and absent in the Patagonian beds are typical Mesozoic genera, while most of those genera found only in the Patagonian beds are unknown from the Cretaceous, and the greater number of genera common to both have been found in different localities throughout the world in both Secondary and Tertiary deposits, and are therefore unimportant in determining the age of either series of beds. If the Lower Patagonian beds really belong to the Cretaceous, since they are of distinctly marine origin, we should find in them some trace of that unusually prolific Cephalopod fauna (*Ammonites*, *Hamites*, *Scaphites*, *Baculites*,

* Neues. Jahrb., etc., Beil. Bd. x, 1896, p. 594.

etc.,) the remains of which are everywhere so abundant in all the known marine Cretaceous deposits of the world, but which are singularly wanting in the Patagonian beds. Since there has not been reported up to the present time a single species characteristic of the Cretaceous period from the *typical* Patagonian beds on the east coast of Patagonia, and since the entire facies of the fauna is Tertiary, there is no good reason, from a paleontological standpoint, for referring any part of this formation to the Cretaceous.

The arguments advanced by Dr. Ameghino for assigning the Lower Patagonian beds to the Upper Cretaceous on account of certain remains of Mosasaurs, Plesiosaurs and fish of Cretaceous types found in the vicinity of Lake Viedma, are of little value, since those beds have never been properly identified as the Patagonian beds.

The stratigraphical evidences in favor of referring the whole of the Patagonian beds to the Tertiary appear to be quite conclusive, assuming that the Guaranitic beds are Upper Cretaceous. That there was a considerable lapse of time between the close of the deposition of the one, and the beginning of that of the other, series of deposits is evidenced by the altered nature of the materials, which show not only that they were derived largely from different sources, but that they were deposited in the one instance in fresh water and in the other in salt water over identically the same geographical districts. Again the appearance of the Guaranitic beds, on the coast at San Julian, where there are no disturbances in the Patagonian beds, can best be accounted for by assuming that they represent a prominence in those beds, due to erosion, which took place after the close of the deposition of the Guaranitic beds and prior to the deposition of the Patagonian beds. Moreover in vast areas, throughout the interior, the Guaranitic beds are immediately overlaid by formations much more recent than Patagonian, thus showing a decided unconformity by overlap between the two series. No interstratification of the two series has ever been observed, which would have been the natural result had they been deposited simultaneously and had marine and fresh-water conditions prevailed at the same time in adjacent regions.

Most of the confusion which has arisen regarding the age of the Patagonian beds, has doubtless been due very largely to the carelessness of collectors. For many years every fossil-bearing horizon discovered anywhere in southern South America and containing a large oyster, was referred without question to the Patagonian beds, and collections were made indiscriminately at many different localities and from many different horizons from the Upper Cretaceous to the Pliocene, all referred to the Patagonian beds and placed in the hands of specialists for

study, often with no other remark than that they were from the Patagonian beds. In this manner, for years, the fauna of the Patagonian beds has been made to include everything from the Upper Cretaceous deposits of the west coast to the Supra-Patagonian beds, the beds in Entre Rios on the Parana and, very likely, some forms from the Cape Fairweather beds of Pliocene age. It is therefore not surprising, in view of this unwarranted association of fossils, that the opinions of conchologists should have varied so much in regard to the age of these beds.

What is especially needed, is a complete series of the invertebrates from the typical localities at the mouth of the Santa Cruz and Desire rivers and the intervening coast, for study and comparison with forms from horizons in both Europe and North America, the age of which has been accurately determined from stratigraphical evidences. With this end in view we made a small collection from near the mouth of the Santa Cruz River, which has been placed in the hands of Dr. A. E. Ortmann, who considers them as not older than Eocene and has thus far identified the following genera and species: *Ostrea hatcheri* (Ort.); *Cucullæa alta* (Sow.); *Pecten* sp.?; *Perna* sp.?; *Arca* sp.?; *Limopsis insolita* (Sow.); *Limopsis aff. araucana* (Phil.); *Cardita patagonica* (Sow.); *C. inaequalis* (Phil.); *Venus meridionalis* (Sow.); *V. volkmanni* (Phil.); *Glycimeris* sp.?; *Dentalium majus* (Sow.)?; *Trochus laevis* (Sow.); *Turritella ambulacrum* (Sow.); *Turritella affinis* (Hup.); *Crepidula gregaria* (Sow.); *Natica obtecta* (Phil.); *Struthiolaria ornata* (Sow.); *Ficula carolina* (d'Orb.); *Voluta* sp.?; *Fusus darwinianus* (Phil.); *Cancer patagonicus* (Phil.).

Incomplete as this collection doubtless is, yet it may be regarded as typical of the beds in question. It is hoped that we may soon be able to make more extensive collections from these beds, but from the evidence already at hand there seems no good reason for referring any part of the Patagonian beds to a more remote age than Eocene.

Miocene.

The Supra-Patagonian Beds.—After the deposition of the Patagonian beds this region was for a considerable period elevated above the level of the sea and subjected to erosion, and doubtless much of the material composing the Patagonian beds was then completely removed over large areas, especially in what is now the interior region. This period of erosion was of sufficient duration to accomplish great changes in the marine fauna of the regions; for in the succeeding strata, which are also of marine origin, there is almost a completely new list in the species represented, while several new genera have been

introduced, and the entire aspect of the fauna changed from Eocene to Miocene, according to Dr. Ortmann, who has also studied our collections of invertebrates from these beds and has identified the following forms: *Ciduris* sp.?; *Scutella* sp.?; *Bryozoa; Terebratula patagonica* (Sow.); *Ostrea phillippii* (Ort.); *O. hatcheri* (Ort.); *Pectunculus* sp.?; *Glycimeris* sp.?; *Fissurella; Solarium; Trochita costellata* (Phil.); *Turritella affinis* (Hup.); *Crepidula gregaria* (Sow.?); *Scalaria rugolosa* (Sow.); *Struthiolaria chilensis; Natica solida* (Sow.); *Balanus varians* (Sow.); *Chthamalus antiquus* (Phil.).

The Supra-Patagonian beds are composed of alternating layers of sandstones and clays, usually of a yellow or light brown color with a rich invertebrate fauna. Ameghino states that they have a thickness of 30 meters, but in the interior, along the base of the Cordilleras, they certainly attain to a much greater thickness, and I should not hesitate to allot to them a thickness of fully 150 meters at Shell Gap, where Lignite Creek emerges from Mayer basin. In this region, as also on the upper Rio Chalia, they rest unconformably upon the Guaranitic beds and dip to the eastward at an angle of about 15° as shown in fig. 3.

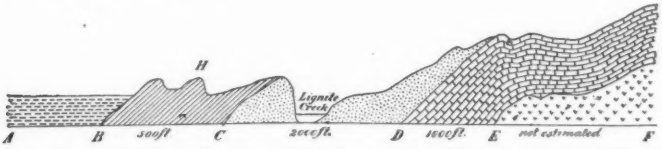

FIG. 3. Section of sedimentary deposits as displayed on south side of Lignite Creek and southern border of Mayer basin, from a point one mile east of Shell Gap to the western border of the basin. A–B. Fresh-water, Santa Cruz beds; B–C. Marine Supra-Patagonian beds; C–D. Fresh-water? Guaranitic beds; D–E Barren sandstones: E–F. Marine Mayer River beds and igneous rocks. Distance from A to F about 15 miles. Relative inclination of strata to base-line. A–F. exaggerated for effect, thus increasing thickness of deposits relatively to length of section displayed.

The Santa Cruz beds.—I cannot agree with Dr. Ameghino in considering the Santa Cruz beds as belonging to the same series with the Supra-Patagonian beds. My reasons for separating them are because the Santa Cruz beds are of fresh or brackish water origin, as shown by the diatoms which they contain;* and also I am brought to this conclusion by the fact that all along the foot hills of the Cordilleras the Supra-Patagonian beds were observed, inclined at high angles, while in the same region the Santa Cruz beds are approximately horizontal and show almost no evidences of disturbance. At Shell Gap, on Lignite Creek, this creek has cut a narrow gorge through the sandstones and clays of the Supra-Pata-

* See Geol. Obs. on S. A., by Darwin, p. 117.

gonian beds, which are here inclined at an angle of not less than 15°, while not more than one-half mile below, on the right bank of the same stream, may be seen an outcrop of sandstones of the Santa Cruz beds, which appear nearly horizontal. In fact, so far as I was able to determine, the inclination of the Santa Cruz beds is nowhere appreciable, except at certain points along the water courses, where it is possible to take in at one view stretches of several miles of the strata, and then there is apparent only a very gentle dip to the southeast.

I nowhere found mammals in the marine beds, nor did I anywhere find the two series interstratified. I observed the contact between the two series at many different localities and did occasionally find bones below the base of the Santa Cruz beds, but they were such as had fallen down from above. On one or two occasions I found bones in strata which were absolutely lower than other strata in the same vicinity where marine invertebrates were abundant, and I at first believed that there had been an interstratification of the two series, but upon careful examination, I found that the layer with the invertebrates did not continue on so as to actually overlie that with the bones, and I was brought to the conclusion that the Santa Cruz beds had here been deposited upon the eroded surface of the Supra-Patagonian beds. An example of this may be seen in a small cañon on the south side of the Rio Chico about two miles below Sierra Oveja. In going up the valley of Chico River it is impossible to be mistaken as to the old crater (*Sierra Oveja*), since it rises directly from the bank of the stream and compels one, if traveling with a vehicle, either to cross the river or go around to the west of the mountain, neither of which routes is particularly good. About two miles below this crater there enters the river valley from the west a narrow, deep cañon. Ascending this cañon some 200 yards, there appears on the south side of it a projecting sandstone ledge, about two feet thick, with an abundance of oyster shells. Proceeding a little farther, the cañon is seen to open out into a small, deeply eroded, "bad land" basin. Continuous all the while on your left is the oyster-bearing, sandstone ledge, which, at a distance of about one-half mile from the mouth of the cañon, becomes covered by talus: this condition continues for perhaps 100 yards, when the section is again clear, and in the lowermost layers there are mammal remains, while the sandstone layer with its oysters is nowhere to be found. It is true that the bottom of the cañon has been all the time rising, but the elevation did not appear sufficient to bring the shell-bearing layer below its surface; I therefore concluded that the sandstone layer with oysters had been eroded away before the deposition of the mammalian beds.

From the high angle of inclination of the Supra-Patagonian beds all along the eastern base of the mountains, it is evident that at the close of that period there were great orographic movements throughout southern South America. Not only were the Cordilleras greatly elevated, but also the region to the eastward, far beyond the present limits of the Atlantic coast, was brought above sea level. The eastern border of this great land mass was perhaps not far to the eastward of the Falkland Islands, and may be approximately represented by an imaginary line connecting these islands with certain outlying bodies of Primary Rock at Port Desire, and other places farther north, and perhaps extending also in a southeasterly direction as far as South Georgia Island. The great development of the Santa Cruz beds along the coast, especially between the Coy and Gallegos Rivers, as well as the very shallow nature of the water between that coast and the Falkland Islands, are both important evidences of a much greater eastward extension of the land during the Santa Cruz period than at present.

Consequent upon the elevation which took place at the close of the Supra-Patagonian period, there was between the borders of the old land-mass, now represented on the east by the Porphyries of Port Desire, and by the Falkland Islands; and on the west by the Cordilleras, a depression, in which were laid down the fresh-water, lacustrine deposits, now known as the Santa Cruz beds, and containing one of the richest and most varied vertebrate faunas known. That the Santa Cruz beds are of fresh-water origin rather than marine is shown by the diatoms. It is also clear from the nature and composition of the strata, that they were not deposited in a great, continuous lake, but rather in a low, flat, marshy country with smaller lakes and connecting water courses. As evidences of this I would cite the numerous examples of cross-bedding, and the fact that the beds of sandstones, clays and conglomerates continually replace one another, both of which facts are well shown in fig. 6 at G and J, and in figures 10 and 11.

The Santa Cruz beds may be separated, according to the vertebrate remains found in them, into an upper and lower horizon. The strata of the lower Santa Cruz beds, as compared with those of the upper, are of a lighter color, more continuous and are composed of finer materials, containing few or no conglomerates. They are best displayed in the bluffs of the Santa Cruz, and of the upper Chalia and Chico Rivers, where they are characterized by the great numbers of herbivorous marsupials and gigantic birds found in them. The upper Santa Cruz beds are best exhibited in the bluffs of the sea and the Gallegos River from Coy Inlet to Guer Aike,

where they are characterized by the scarcity of herbivorous marsupials and bird remains and the abundance of the remains of carnivorous marsupials, edentates, ungulates, rodents, etc.

There has been much doubt in regard to the age of the Santa Cruz beds. Darwin* was the first to determine that they were distinct from the Patagonian beds and to suggest their true stratigraphic position in regard to the latter. Dr. Florentino Ameghino† and his brother Carlos Ameghino, during the first five years of their labors on the mammalian fauna of the Santa Cruz beds, supposed them to underlie the Patagonian beds which most conchologists agree in referring to the Eocene. They therefore considered the Santa Cruz beds as Lower Eocene and the Patagonian beds Upper Eocene. Finally on his sixth journey into this region Carlos Ameghino was able to determine the exact stratigraphic relations of these deposits, and their relative position in the Tertiary scale was exactly reversed.

So far as any observations bearing upon the stratigraphic relations of the Santa Cruz beds are concerned, there is absolutely nothing against referring to them any age from Lower Miocene to Lower Pliocene. That they are not older than Middle Miocene is pretty clearly shown, since they have been seen to rest unconformably upon the Supra-Patagonian beds, in regard to the invertebrate fauna of which Dr. Ortmann writes as follows: "The most interesting form of the Supra-Patagonian beds is the *Scutella*. According to Zittel (*Handbuch der Palaeontologie*, vol. i, p. 522), all the species of *Scutella* are found in the Oligocene and Miocene; so that this fact tends to confirm Moericke's opinion (N. Jahrb. Min., etc., Beil. Bd. x, pp. 593 and 596) of the Miocene age of the Patagonian beds, at least of a part of the so-called Patagonian beds. If this is true, the Santa Cruz beds overlying the Scutella beds cannot be Eocene."

In any attempt to correlate the Santa Cruz beds with other Tertiary strata of either Europe or North America, nothing will be found of more value than the remarkable vertebrate fauna which they contain. There is absolutely no ground, from a stratigraphical standpoint, for presuming that the mammalia of this region were any more advanced in early Tertiary times than were the mammalia of the northern hemisphere; hence, notwithstanding the fact, that the Santa Cruz fauna is so dissimilar to any known in either Europe or North America, if among the ungulates, rodents and other orders common to

* See Geol. Obs. on S. A., Darwin, p. 117.

† See Énumeration Synoptique des Espèces de Mamifères Fossiles des Formations Éocènes de Patagonie, par Florentino Ameghino, pp. 4–5 (Buenos Aires), 1894.

both, forms are found, no matter how dissimilar they may be, yet showing approximately the same degree of development along those lines of progression common to both, it is only fair to consider beds containing such forms as of approximately the same geological age, and such correlation of the deposits of Patagonia will, it is believed, receive the sanction of most paleontologists and geologists, until good reasons are produced to show that it is at fault. It was largely for the purpose of securing material with which to make such comparisons that our expedition to Patagonia was undertaken. Several tons of most excellent fossils were procured from various horizons in the Santa Cruz beds, among which are the skulls and greater portions of the skeletons of nearly every genus reported from these beds. This material is being rapidly freed from the matrix and prepared for study, and in a short time it will be possible to compare these forms, point for point, with the skeletons of animals found in our own Tertiary deposits, the age of which has been determined beyond reasonable doubt, both from paleontological and stratigraphical evidences. While the final results of such comparisons are yet to be attained, enough has already been done to demonstrate the comparatively modern aspect of the fauna of the Upper Santa Cruz beds. For the benefit of those interested and who may not have had an opportunity of studying for themselves the figures and descriptions already published by Dr. Ameghino, I present here in figs. 4, 4*a*, 5, the metatarsals and superior dentition of one of the Proterotheridæ, drawn from part of No. 15107 in our collection. Note the complex structure of the molars and pre-molars, the molariform condition of the latter, the long diastema, the absence of incisors, etc., in the dentition, while in the metatarsals there is the very great tendency to monodactylism, as shown by the rudimentary character of metatarsals II and IV, and the extremely well-developed metapodial keel on metatarsal III. These or other characters, equally indicative of a high degree of specialization, are met with in nearly every group of animals in these beds. In consideration of the stratigraphic position of the Santa Cruz beds and the degree of specialization exhibited by the mammalian remains found in them, it is difficult to see how they can pertain to a period more remote than Miocene.

Pliocene.

The Cape Fairweather beds.—In this Journal for September last, the author described and gave a section of certain marine deposits found near Cape Fairweather, overlying the Santa Cruz beds, and named them the *Cape Fairweather beds.* At

that time I had not seen Dr. Ameghino's article entitled "Notes on the Geology and Paleontology of Argentina,"* in which he gives the first notice of marine deposits, found in this region, overlying the Santa Cruz beds. My observations regarding the relations of these marine beds to the Shingle formation (*Tehuelche formation of Ameghino*) do not agree with those of Señor Carlos Ameghino. Dr. Ameghino, on page 17 of the paper just cited, after quoting at some length from a letter from Carlos Ameghino, concludes: "According to this the bowlders were deposited at the bottom of the sea,

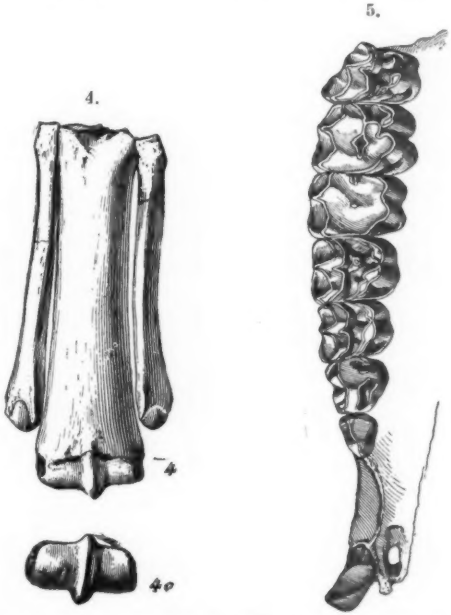

FIG. 4. Front view of metatarsals of *Diadiaphorus majusculus?* Amegh. from No. 15107 Princ. col.. fig. 4a: view of distal end of metatarsal III, showing great development of metapodial keel.

FIG. 5. Crown view of sup. dentition of *Diadiaphorus majusculus?* Amegh. from No. 15107, Princ. col.

and over them there extended at other periods a vast formation of marine shells, of which there only remains diminished traces at certain definite spots." This is exactly the opposite of what I observed near Cape Fairweather on the coast, where there is a splendid continuous section from the Shingle formation through the Cape Fairweather beds and some 300 feet of

* See Geol. Mag., January, 1897, pp. 4–20.

the Santa Cruz beds, and where it is absolutely impossible to mistake the relative position of the series of deposits. As shown in the section given in my original description of these beds, and reproduced here in fig. 6, the beds with marine invertebrates underlie the Shingle formation.

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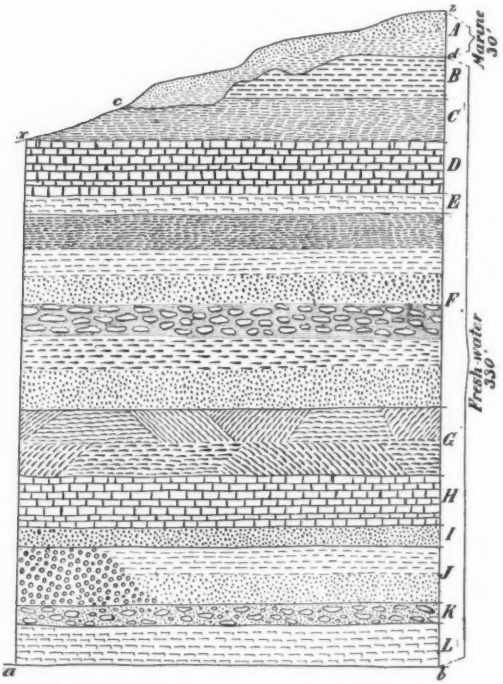

FIG. 6. Section near Cape Fairweather showing relations between Cape Fairweather and Santa Cruz beds. *b–d.* Santa Cruz beds. *d–z.* Marine beds, consisting below of Cape Fairweather beds and above of the bowlder formation. *c–d.* Contact between Cape Fairweather and Santa Cruz beds.

I provisionally correlated the Cape Fairweather beds with certain deposits discovered by Darwin at San Sebastian Bay on the east coast of Tierra del Fuego. Until the fauna of the latter beds is known, it will be impossible to verify the accuracy of this correlation. The aspect of the very meagre fauna found in them by Darwin, as well as the very considerable increase in thickness to which they attain at San Sebastian, are both important evidences in favor of this correlation; for as mentioned in my previous paper, all the Tertiary deposits of

this region increase in thickness as we proceed southward along the coast, and appear first toward the north capping the summits of the higher table lands, then farther south they are brought to the water's level by a slight southeasterly dip, and finally, still farther south, they entirely disappear beneath the sea.

In discussing the age of these marine beds Dr. Ameghino refers them to the Miocene because they contain oysters "of large size and of a species similar to that characterizing the Santa Cruz formation." Prof. Henry A. Pilsbry, who has studied our first collections from these beds and already published in the Proc. of the Phil. Acad. of Sci. a list, with descriptions of new species, refers these beds to the Pliocene. He has furnished me the following list of species: *Trophon laciniatus* Martyn, *T. inornatus* Pilsbry, *Calyptræa mammillaris* Brod. (?), *Turritella innotabilis* Pilsbry, *Cardium* sp. indet., *Pecten actinodes* Sowb., *Ostrea ferarresi* Orb.,* *O.* n. sp., *Pinna* sp. indet., *Magellania venosa* Sol. Of these he remarks "*Trophon laciniatus*, *Magellania venosa* and the *Calyptræa* are living species. The Cardium and Pinna may also be living. The others are extinct, but the Turitella is closely allied to a living Chilian form." We have since sent Dr. Pilsbry additional material which will enable him to nearly double the list of species, and which, he says, only confirms the Pliocene age of the beds.

The Tehuelche or Shingle Formation.—The presence of the Cape Fairweather beds with an abundant marine fauna, above the Santa Cruz beds, is positive proof of the submergence of this region. That this submergence took place long after the close of the Santa Cruz period can, I think, be well demonstrated, for, as shown in fig. 6, the Cape Fairweather beds are seen to rest upon the eroded surface of the Santa Cruz beds. This unconformity by erosion cannot be considered as due to a secondary deposition of the materials of the Cape Fairweather beds on the surface of the slope of the cañon where the section was made, for the two strata of bowlders and sandstones are here quite distinct, and show no mingling of materials, such as would have resulted from secondary deposition. Moreover the same unconformity is observable a little farther north in a section exposed for a long distance and where an absolutely level plain prevails above, as shown in fig. 7.

From these facts and others to be mentioned later, I conclude that after the deposition of the Santa Cruz beds and prior to the deposition of the Cape Fairweather beds this region was for a considerable period above sea level and subjected to erosion; during this period of erosion all the more

* In regard to the identification of the large oysters of Patagonia see paper by Dr. A. E. Ortmann in this number of this Journal, p. 355.

important water courses and many of the minor ones, which now exist, were outlined. After this, there was a subsidence sufficient to cause a submergence of this region beneath the sea, which prevailed in Pliocene times for a period ample for the deposition of the Cape Fairweather beds. Toward the close of the Pliocene there began a gradual elevation of this

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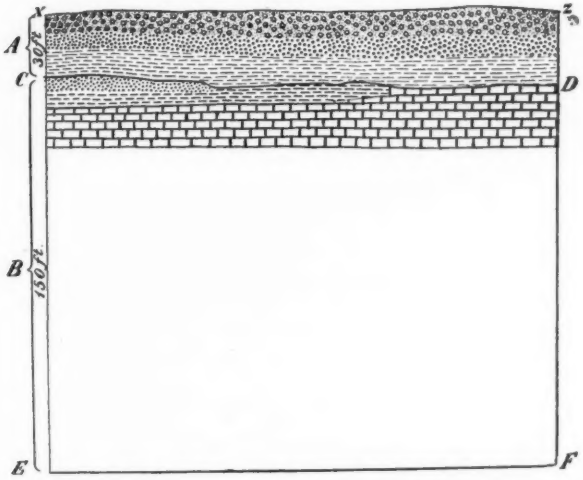

FIG. 7. Section showing unconformity by erosion between Cape Fairweather and Santa Cruz beds, made from top of land slide just north of section shown in fig. 6. *B.* Upper 150 feet of S. C. beds; *A.* Marine C. F. beds, composed below of sandstones with marine invertebrates and above of bowlder formation.

area, during which the great bowlder formation was deposited by the combined action of ice and water, and which resulted in bringing this region permanently above sea level. There can be little doubt that the origin of the numerous small salt lakes which now occur all over this region, and which occupy depressions in the surface of the plains, frequently several hundred feet in depth, dates from this period, and that they are due to confined bodies of salt water left in these depressions by the receding sea. Such depressions were, at some period during the elevation of this area, bays, formed usually near the source of small drainage channels tributary to the more important water courses, which existed in the former period of erosion. Across the mouths of these shallow bays there were thrown, by the tides, bars composed of sand and shingle which, as the elevation continued, confined considerable bodies of sea-water. If in such a body of water the loss by evaporation exceeded the gain by tributaries, there would be a gradual decrease in the

volume of water, until an equilibrium was reached, which would result in a small body of concentrated salt water, often with a deposit of salt at the bottom, due to precipitation from an oversaturated solution. This is exactly what is found to be the case in hundreds of places in this region. In all of these salt lakes the bluffs are always much lower on one side than on any of the other sides, and it is quite apparent that the present drainage system corresponds very closely with that of the former period of erosion.

Sketch map of Argentine territory of Santa Cruz.

That the salt in these lakes has been derived from confined bodies of sea water and has not been leached from the surrounding bluffs, is clearly shown by the numerous springs of sweet water in many places, alongside of the salt lakes. All the streams and springs of this region have good fresh water. We never saw a single spring the waters of which were saline, and the surface of the ground is everywhere remarkably free from incrustations by any alkaline or other salts.

I have already stated that the deposition and distribution of the great bowlder formation was accomplished by the combined action of water and ice. The facts which have led to this conclusion are the great quantity of material left as rounded hillocks, composed of heterogeneous masses of angular rocks, often of great size, polished bowlders and much fine-grained, silted material, occurring as moraines all along the base of the mountains and sometimes extending for some distance out on the plains. Another fact also observed and bearing directly upon this question is the distribution throughout this formation of immense bowlders, which could not possibly have been transported to their present position by any other agency than that of ice. The number of these large, massive bowlders rapidly decreases to the eastward after reaching a point about thirty miles east of the Cordilleras, but they are found, though rarely, even as far east as the present coast. As an instance of this I may mention that one of these bowlders, weighing several thousand pounds, may be seen on the bluffs of the south side of the Rio Chico about ten miles below the mouth of Rio Chalia. It lies on the north side of and only a few yards from the road which leads from the port of Santa Cruz to the settlements on the lower Rio Chico. Its position is approximately shown on the map at the point marked +B. From the present position of this rock, weighing not less than 6000 pounds, to the mountains, is a distance of 200 miles, and it does not seem possible that this immense bowlder could have been transported that distance by any other agency than that of ice. I therefore conclude that, along with the elevation there were in the Cordilleras great accumulations of snow and ice, which produced glaciers extending out beyond the foot hills of the mountains even as far as the, at that time, eastern border of the sea. The glaciers no doubt transported most of the material now constituting the great bowlder formation from the Cordilleras to the sea, where it was afterwards distributed over the region to the eastward by the combined action of water and ice, either in the form of icebergs or floating shore and river ice. This would account for the enormously greater development of the bowlder formation near the Cordilleras than distant from them; for the gradually decreasing size of the rocks of which it is formed as we proceed eastward from the mountains, both of which facts have been observed and commented upon by Darwin; and also for the occasional occurrence in the formation of large bowlders in places far removed from the mountains, and which were doubtless carried by icebergs direct from the glaciers to their present positions.

Later Sedimentary Deposits.

In the region visited there are other sedimentary deposits, usually of very limited extent and evidently of quite recent origin. My observations do not warrant any very definite opinions regarding the origin or exact age of any of these deposits. Among them I may mention some of loess (?) in the

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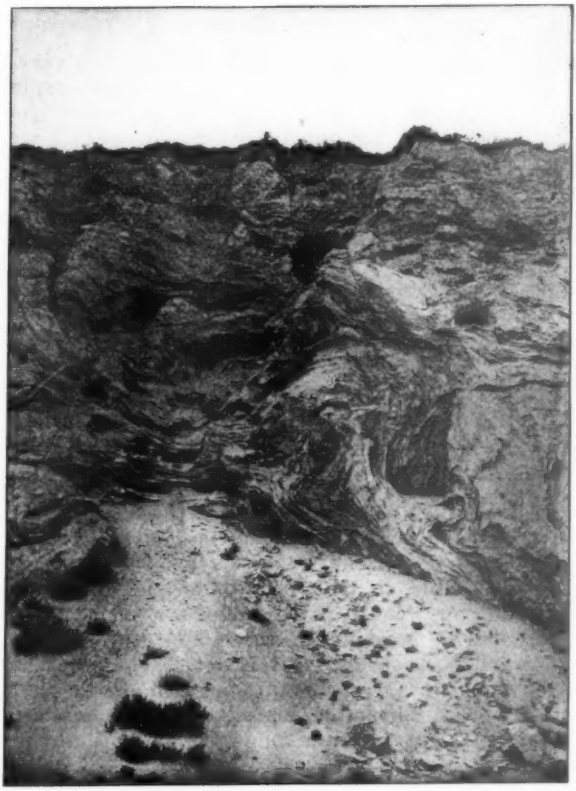

FIG. 8. Example of wind erosion on south fork of Rio Chico, Patagonia, from a photograph by the author.

high bluffs north of the Gallegos River, just west of Killik Aike. They rest unconformably upon the Santa Cruz beds, are about 40 feet thick and are composed of very fine sand

showing stratification toward the bottom, where we found the lignitized stems of small plants and parts of the skeletons of two rodents.

Important deposits of loess (?) were observed on the south fork of the Rio Chico, which may be really aqueous deposits belonging to the bowlder formation. They are best exposed in the bluffs of the stream, where they show beautiful examples of wind erosion, a section of which is shown here in fig. 8.

Igneous Rocks.

Darwin, on ascending the Santa Cruz River, was very much struck by the beds of basalt which he observed capping the bluffs on either side of the stream at places remote from the Cordilleras, which he not unnaturally concluded had been the source of all the basalts of this region. He considered these basalts as examples of long distance lava flows over a bed only very slightly inclined. Had Darwin gone overland into the interior, instead of up the Santa Cruz River, he could not have failed to discover that the source of these lava beds was not the Cordilleras, but numerous small craters, found often in the immediate vicinity. There is a group of these craters only a few miles inland, near the mouth of the Gallegos River; they are most numerous over an area about forty miles in breadth, extending across the country from north to south, and distant about 80 to 120 miles from the mountains. It is sometimes possible to travel more than 100 miles between this chain of craters and the Cordilleras without passing over a single lava bed, especially in the district south of the Santa Cruz River.

Notwithstanding that these craters exist in such great numbers all over the plains of Patagonia and penetrate right through the strata of the Santa Cruz beds, yet there was nowhere observable, in their vicinity, any faulting or disturbance of the latter I can only account for this on the theory, that these craters were in existence and active prior to and during the deposition of the Santa Cruz beds. I have no doubt that they were the source from which was derived much of the material of the latter deposits, since the latter are very largely composed of volcanic conglomerates and ash, as stated by Darwin.

It is also evident that many of these craters continued active long after the deposition of the Santa Cruz beds, for many of the lava flows may still be seen, in places, descending from the plains down over the slopes into the valleys of the water courses, showing that the latter had been eroded prior to the flow of streams exhibiting such conformation.

Many of the craters show, especially in their lower parts, a

well defined columnar structure; while toward the top they are usually composed of great masses of vesicular slags and cinders with bright colors, jet black, steel blue, crimson and yellow predominating. One of these is shown in fig. 9. The columnar structure may be seen on the left near the base, while toward the summit only cinders and slags prevail. The two small "windows" on the left have suggested the name *Sierra Ventana.* It is on the right bank of the Rio Chico about 75 miles above the mouth of the Rio Chalia and rises to a height of perhaps 1200 feet.

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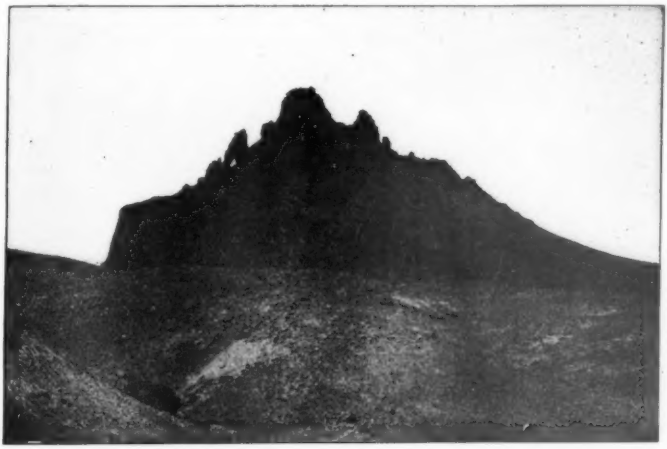

FIG. 9. Sierra Ventana, Rio Chico, Patagonia, from a photo. by the author.

The Transverse Valleys of Patagonia.

Dr. Florentino Ameghino, in his "Notes on the Geology and Paleontology of Argentina," after discussing at some length the bowlder formation, takes up the origin of the transverse valleys of Patagonia. Since it appears to me that Dr. Ameghino is entirely wrong here, not only in his conclusions but also in his statement of facts, I quote him fully on this question. He says, on page 18: "Having now dispelled the ignorance as to the origin of the bowlder formation, this leads us naturally to determine the age of the formation of the transverse valleys of Patagonia. It is evident that at the bottom of the ancient sea in which the bowlders were deposited, these were scattered by the waters in a uniform manner over all the submerged territory. The same may be said of the sheets of

basalt; these also must have extended in a comparatively uniform manner, without forming the steep cliffs which they exhibit to-day in the river valleys. Darwin, speaking of the scarps of the valley of the river Santa Cruz, said that the cliffs of basalt of the two opposite sides were recognizable immediately as at one time forming a continuous bed. The same may be said of the beds of bowlders which in many parts form the opposite cliffs of the Patagonian valleys; those beds were continuous across the valleys, but there are now no traces of them.

"It is evident that if the valleys had existed before the great marine submergence referred to, they would have been completely filled with marine deposits, which, even supposing they had been swept away afterwards by the waters, would always have left numerous traces buried in the innumerable angles of the slopes; but as such deposits do not exist, the inevitable conclusion is, that the formation of the great transverse valleys of Patagonia was brought about by great dislocations and gigantic faults at a comparatively recent geological period, posterior to the bowlder formation and at the last emergence of the land."

If, as Dr. Ameghino states, "it is evident that at the bottom of the ancient sea in which the bowlders were deposited these were scattered by the waters in a uniform manner over all the submerged territory," is it consequently evident, as he concludes, that "if the valleys had existed before the great marine submergence referred to, they would have been completely filled with marine deposits," when these valleys are all many times deeper than the entire thickness of the bowlder formation? It certainly is not evident that these valleys would have been completely filled with marine deposits; but it is quite evident, that over their slopes and in their bottoms there would have been deposited a layer of bowlders, at least equalling in thickness that of the bowlder beds of the table lands. It is further evident, that supposing they had been afterwards swept away by the waters, they would have left numerous deposits buried in the innumerable angles of the slopes; and this is just what is to be seen in the sides of the cañons and larger water courses at almost every section shown along the coast or elsewhere. In fig. 6 are shown not only the bowlder formation but also the underlying Cape Fairweather beds, both occupying angles in the slope. In figs. 10 and 11 the remnants of the bowlder formation are shown occupying angles in the slopes of the cañons along this coast. At the points where both the latter sections are shown, it is quite possible to determine the relative amount of erosion which has taken place prior to and since the deposition of the bowlder formation.

Now, again, if, as Dr. Ameghino states: "The inevitable conclusion is, that the formation of the great transverse valleys of Patagonia was brought about by great dislocations and

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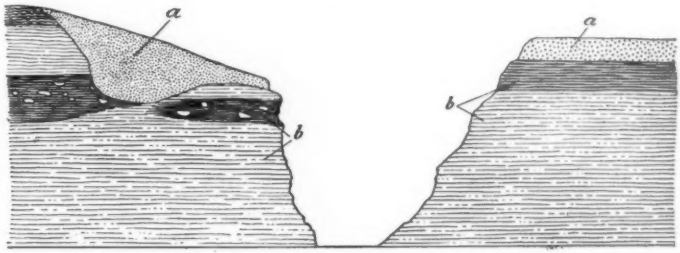

FIG. 10. Section as displayed in bluffs of coast at Corriken Aike about 18 miles south of Coy Inlet, showing the bowlder formation occupying angles in the slope of the cañon. *a*. Bowlder formation. *b*. Santa Cruz beds.

gigantic faults at a comparatively recent geological period, posterior to the bowlder formation and at the last emergence of the land"; how could these beds of basalt and bowlders now

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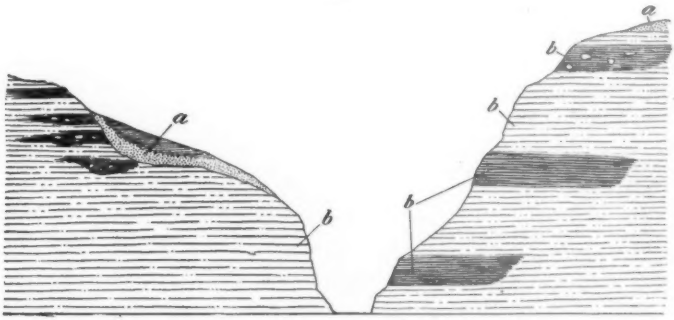


FIG. 11. Section as displayed in bluffs of sea coast at mouth of cañon about 10 miles south of Coy Inlet, showing bowlder formation occupying angles in slope of cañon. *b*. Represents S. C. beds; *a*. Bowlder formation covered by heterogeneous material of secondary deposition accumulated during the present period of erosion. The dark areas shown in both the above sections in the S. C. beds are composed of discontinuous strata of heavily bedded sandstones enclosing large concretions shown as white areas on the sketch.

form opposite cliffs of the valleys, as he has stated above? If there are such gigantic faults in this region, surely there should have been ere this some recorded observation concerning them. In so far as I know, no one has ever observed any dislocation

in these beds. My own impression was that the different strata on opposite sides of any given water course were remarkably similar and easily identified. Darwin also states, on page 119 of his "Geological Observations on South America," that the land in this region has been upraised without the strata having been in a single instance, as far as his observations went, unequally tilted or dislocated by a fault. I think it has now been pretty clearly shown that the transverse valleys of Patagonia are due to erosion, and that this erosion was partially accomplished before the deposition of the bowlder formation. The lava beds, which now form opposite cliffs of the same valley, had their origin either during the deposition of the Santa Cruz beds or *immediately* after, and before any considerable erosion had taken place; while those showing conformation with an eroded surface—and there are many such—were ejected long after the close of the Santa Cruz period.

As an aid to others intending to visit this country for the purpose of collecting fossils, the following suggestions as to localities may be of some service. I have already indicated on the map the most promising localities for fossils in the Santa Cruz beds. I should especially recommend the bluffs on the north side of the Gallegos River from Guer Aike to a point opposite Gallegos; and the beach, below the bluffs, laid bare at low tide, on the coast between Corriken Aike and Coy Inlet. In the interior there are very promising localities in the bluffs of the Santa Cruz, Chalia and Chico rivers, and over a large area between the last two streams lying directly south of Sierra Ventana.

Princeton University, Sept. 26, 1897.

Art. XXXVIII.—*On some of the large Oysters of Patagonia;* by Dr. Arnold E. Ortmann. With Plate XI.

Since there is much confusion in regard to the identification of the giant oysters of Patagonia, it seems well to describe briefly those forms collected by Mr. Hatcher, and to give their proper geological relations.

1. *Ostrea hatcheri* nov. spec. (Plate XI, fig. 1.)

Shell almost circular in outline, very thick, lower valve concave, the upper valve less concave. Beak of upper valve only slightly projecting beyond that of the lower one. Area broadly triangular, much broader than long, a little more than $\frac{1}{3}$ as broad as the shell. Ligament groove comparatively shallow, about as broad as the lateral parts of the area. Anterior margin of muscular impression situated exactly in the middle of the inner surface of the shell (without area).

Measurements of the type: Length, 169^{mm}; breadth, 158^{mm}; thickness of lower valve, *ca.* 35^{mm}; breadth of area (lower valve), 54^{mm}; length of area, *ca.* 25^{mm}.

There is no doubt that this species has been seen by others, especially by Darwin, but it has been generally taken for *O. patagonica*. The chief differences between it and the latter are the following: 1. The outline of the shell is almost circular, in striking contrast to the subtriangular form of *O. patagonica*. 2. In *O. hatcheri* the area is comparatively broader and the beaks are not so produced as in *O. patagonica*, in which the area is only a little shorter than broad.

O. hatcheri, in its external form, comes very near to *O. maxima* Hup. (Philippi, Foss. Terc. Cuart. Chile, 1887, Pl. 48, fig. 1), but it is at once distinguished by the situation of the muscular impression and the shape of the area, which is decidedly broader in *O. maxima*. Moericke (N. Jahrb. Min., etc., Beil. Bd. x, 1896, p. 575), in comparing *O. maxima* and *patagonica*, has already stated these differences. Since he refers to an *O. patagonica* from "Santa Cruz," it seems as if he mistook specimens of *O. hatcheri* for *patagonica*, and used them for comparison, and not d'Orbigny's figure of the latter. The outline of the true *patagonica* cannot be compared with that of *maxima*.

Localities: The type comes from the Patagonian beds of Santa Cruz (about 250 feet above high tide). Smaller and larger specimens have been found in the Supra-Patagonian beds of Upper Rio Chalia and Shell Gap. One from the latter locality measures: Length, 212^{mm}; breadth, 194^{mm}; thickness, *ca.* 50^{mm} (upper valve).

2. ***Ostrea philippii*** **nov. nom. (Plate XI, fig. 2.)**

Ostrea bourgeoisi Philippi, l. c., p. 207, pl. 48, fig. 3.

This species is characterized by its elongate-ovate form and its elongate-triangular area. It attains a considerable size and thickness (length, 236^{mm}; breadth, 130^{mm}; thickness, *ca.* 110^{mm}), and may have been also mistaken for *O. patagonica*. In our specimens the beak of the lower valve is longitudinally incurved, and in a few specimens this curve is very strongly pronounced.

I do not believe that this species is identical with the true *O. bourgeoisi* from the Californian Pliocene (Rémond, Proc. Calif. Ac., 1863, p. 13, and Gabb, Geol. Surv. Calif. Pal. ii, 1869, p. 33, pl. 11, fig. 57), since the most important character of the latter, the constriction of the shell near the cardinal area, is not represented in Philippi's figure, and is not exhibited by any of our specimens.

Localities: Very abundant in the Supra-Patagonian beds of Upper Rio Chalia and at Shell Gap on Upper Rio Chico. Philippi quotes it from Punta Arenas.

3. ***Ostrea patagonica*** **d'Orb.**

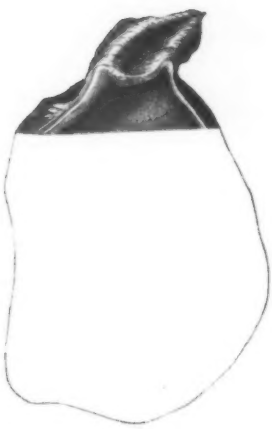
d'Orbigny, Voy. Amer. Merid. Pal., 1842, p. 133, pl. 7, fig. 14–16. Philippi l. c., p. 205, pl. 48, fig. 2.

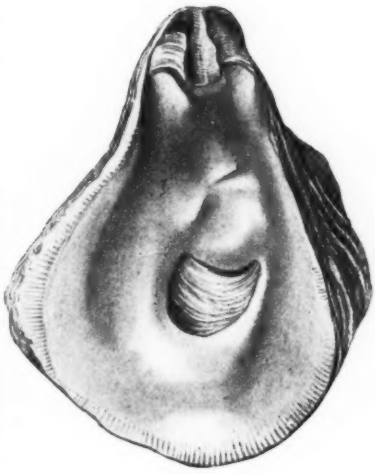
This species differs from *O. philippii* by its subtriangular (not ovate) outline and the shortness of the beak and area.

O. patagonica seems to be restricted to the more recent beds of the South American Tertiary, since d'Orbigny's types are from Entre Rios, and most of the other localities given by him are situated in the northern parts of Argentina, where the older (Eocene or Miocene) beds seem to be absent. There has been much confusion as to this fossil, since almost all large oysters found in Patagonia have been called by this name. But in the true Patagonian beds and in the Supra-Patagonian beds *O. patagonica* is entirely wanting, *O. hatcheri* and *philippii* having taken its place.

There are numerous specimens of a large oyster in our collection from the probably Pliocene Cape Fairweather beds, which resemble very closely *O. patagonica*, but the muscular impression in all our specimens is situated nearer to the posterior margin of the valve than in d'Orbigny's figure. This Cape Fairweather oyster may be identical with *O. patagonica* or may represent, as Mr. Pilsbry believes, a new species; at any rate, it is closely allied to *O. patagonica*.

I present here a comparative plate giving the internal views of the lower valve of our types of *O. hatcheri* and *philippii*, as well as the reproduction of the original figures of *O. bourgeoisi* (pl. XI, fig. 3) combined from Gabb's fig. 57^a and 57^b (on pl. 7, l. c.), and a copy (pl. XI, fig. 4) of d'Orbigny's original figure of *O. patagonica* (l. c., pl. 7, fig. 14).





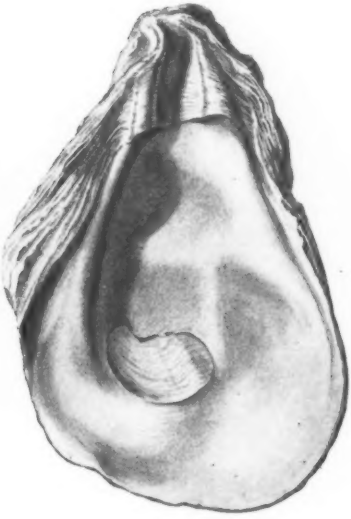


FIG. 1.—*Ostrea hatcheri* n. sp. One-third natural size.
FIG. 2.—*Ostrea philippii* n. sp. One-half natural size.
FIG. 3.—*Ostrea bourgeoisi* Rém. One-half natural size (copy).
FIG. 4.—*Ostrea patagonica* d'Orb. One-third natural size (copy).

ART. XXXIX.—*The former Extension of the Appalachians across Mississippi, Louisiana, and Texas;* by JOHN C. BRANNER.

Introductory.

SEVERAL years ago I stated that *the old Appalachian land area crossed what is now the lower Mississippi Valley* from northern Alabama to the pre Cambrian area northwest of Austin, Texas.* I have not published the evidence that seems to support this theory, partly because the work I was doing in the State of Arkansas was constantly adding new facts to the information already in hand. The recent publication by Dr. Henry S. Williams of his paper on the Southern Devonian† induces me to give the results of my observations in connection with this subject in the hope that they may help toward the solution of the interesting problem he discusses, and toward the collection of data concerning the ancient physical geography of the southern states.

The Cretaceous embayment.

Orographic changes, probably dating about the close of the Jurassic, lowered a large area in Mississippi, Louisiana, Texas and southern Arkansas, admitting the sea across the former land as far north as southern Illinois. This embayment and its subsequent history are described by Hilgard,‡ and hardly call for detailed description or discussion here. Lower Cretaceous rocks in Arkansas, Indian Territory, Texas, Alabama and Mississippi rest unconformably upon the upturned edges of Coal Measures rocks. These Cretaceous beds cross Arkansas from southwest to northeast, and cross Alabama and Mississippi from southeast to northwest, and Tennessee from south to north. These facts are enough to show that this embayment took place at or about the beginning of Cretaceous time, and that it was caused by a depression in the region over which these sediments are spread. The present paper will deal principally with the extent of this depression.

Evidence, Character and Extent of the Southwestern Appalachian Depression.

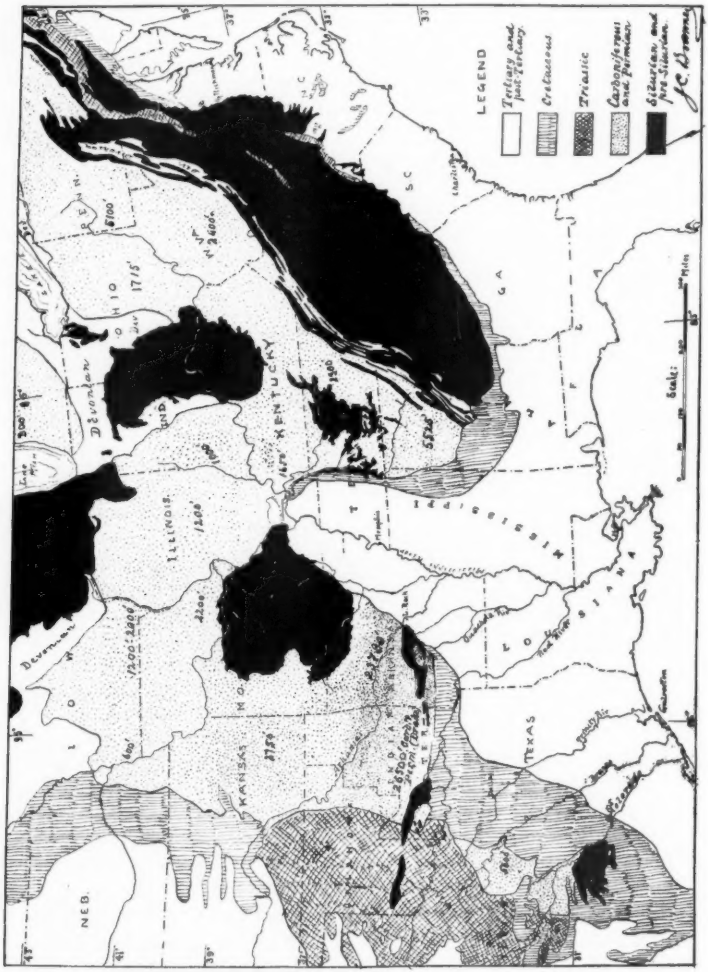
The extent and character of the depression that admitted the Cretaceous sea across the Paleozoic rocks of Arkansas, Texas,

* Geol. Sur. of Arkansas, Ann. Rep. for 1890, vol. iii, 213; Proc. Bost. Soc. Nat. Hist., xxvi. 477.

† This Journal, May, 1897, pp. 393–403.

‡ Geol. History of the Gulf of Mexico, by E. W. Hilgard, this Journal, vol. cii, 391–404; Proc. A. A. A. S, xx, 222–236; Smithsonian Contributions, No. 248.

Louisiana, Mississippi and Tennessee are shown by a considerable number of facts, some of which, if taken alone, have but little weight, but pointing, as they do, all in the same direction, they make a reasonably strong case.



*The Reversal of the Arkansas drainage.**—In studying the origin of the lower Mississippi the possibility of the headwater

* See also Origin of the Lower Mississippi, by L. S. Griswold, Proc. Bost. Soc. Nat. Hist., xxvi, 474–479.

extension of some small south-flowing stream has been taken into consideration, but such an hypothesis claims little attention in this case. The lower Mississippi since Cretaceous times must be either the direct descendant of Carboniferous drainage, or else it has been produced by a depression in the lower Mississippi area which also caused a reversal of the Arkansas Valley drainage. Let us first consider the reasons for believing the drainage of the Arkansas reversed.

On any emerging coast the streams flow from the older toward the newer beds. Along the Atlantic slope the streams flow from the Paleozoic uplands across Triassic, Cretaceous, Tertiary, Pleistocene and recent deposits into an ocean where sediments are actually being laid down. In the same way the emerging Carboniferous lands must have had their drainage flowing from new Carboniferous beds into Permian seas, and later, as emergence proceeded, these streams must have flowed across Permian sediments into Triassic waters, and so on, as long as the orographic movements were even. Now in Arkansas the succession of the beds, in the order of their deposition from the Carboniferous upwards, is found by going westward up the Arkansas and Canadian rivers into Indian Territory and Oklahoma. Along such a section one passes from the Lower to the Upper Coal Measures, thence to the Permian, Triassic, Cretaceous, and Tertiary in their order; and this must have been the direction of the drainage while these beds were being deposited. That is, the sea that occasionally invaded this region receded westward and was gradually crowded in between the Ozarks and the Rocky Mountains. Further, the area between the Ozarks and the Ouachita uplift is structurally a great synclinal trough dipping westward. These structural features must have determined the direction of the drainage during Carboniferous and later times. The Arkansas river therefore flows, not with the dip of the rocks, as it did originally, but against it. Such a state of affairs would be brought about by the lowering of the Mississippi River region. The amount of depression necessary to reverse the drainage is given on p. 360, under the head of the "Slope of the Ouachita uplift."

Although Cretaceous and Tertiary beds fill the Mississippi embayment, there are neither Permian, Triassic nor Jurassic rocks exposed anywhere beneath them or along their edges. Whatever may have happened in the lower Mississippi area, it is therefore reasonable to suppose that the drainage flowed westward through the Arkansas Valley during Carboniferous, Triassic and Jurassic times, and entered the Mediterranean sea that lay along the eastern base of the Rocky Mountains. And the reason for this westward Carboniferous and later drainage

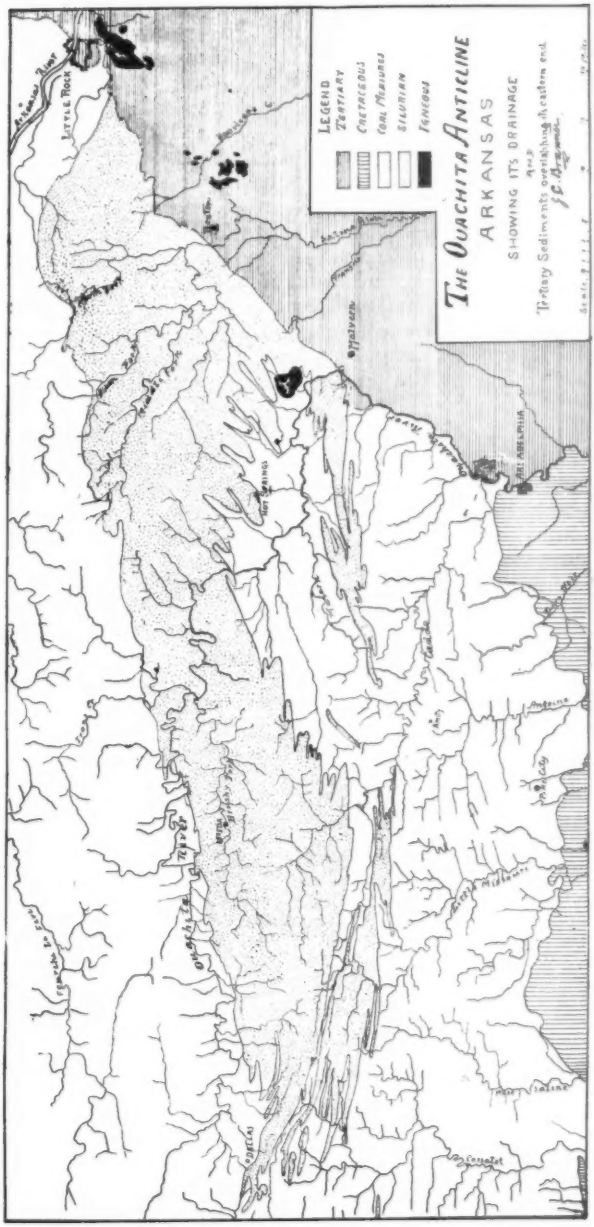
was probably the barrier made by the Ouachita anticline and its eastward and westward extension.

Reversed Carboniferous drainage in Texas.—In Texas there has been a similar reversal of the drainage over the Carboniferous area. Even now, and in spite of an eastward tilting of the region, the Carboniferous rocks of Central Texas dip gently westward while the Colorado, Brazos and Red rivers flow southeast or eastward against the dip. Dr. N. F. Drake, who studied the area, believes, from internal evidence, that the sediment came from the east.* They are said by Professor Hill to have been covered by Cretaceous rocks :† in this case the present southeast drainage across the Carboniferous has been superimposed, but in any event it has been reversed. Additional evidence of the southeastward origin of the Carboniferous sediments of central Texas is given under the head of "Carboniferous sediments."

The submerged end of the Ouachita uplift.—A geologic map of the State of Arkansas shows the Ouachita anticline to have an east-west axis and a core of Lower Silurian rocks (though some of them may be older). The western end of this anticline tapers to a point in the western part of the state, and the Lower Coal Measures rocks swing round and dip away from it on all sides. It is reasonable to suppose that its eastern end had a more or less similar form, but it is now concealed by Cretaceous and Tertiary rocks that lap over and across it in such a manner as to give it the appearance of having been cut almost square across—an appearance that could have been produced only by the lowering of this eastern end beneath the Cretaceous and Tertiary seas, and the deposition of their sediments upon it. (See accompanying plate showing the Ouachita anticline.)

Slope of the Ouachita uplift.—The slope of the Ouachita uplift is toward the east. This is true both of the general surface and of the higher elevations over the entire area. The general level of the highest of the Silurian peaks about the eastern end of the Ouachita anticline is between 500 and 600 feet above sea level, while the general elevation of the same novaculite rocks about Hot Springs is about 1200 feet, and south of Dallas, Arkansas, at the western end of the anticline, about 1900 feet. The greatest elevations in the western part of the state, however, are in Lower Coal Measures rocks: the highest of these are between 2750 and 2825 feet; Shinall Mountain, the highest mountain of Carboniferous rocks at the eastern end of the Carboniferous area, is 1050 feet high, while most of the high points about this eastern end are between

* Fourth Ann. Rep. Geol. Survey of Texas, 1892, p. 373.
† Bull. Geol. Soc. Amer., ii, 527.


LEGEND
Tertiary
Cretaceous
Coal Measures
Silurian
Fenous
THE OUACHITA ANTICLINE
ARKANSAS
SHOWING ITS DRAINAGE
AREA
Little Rock
Arkadelphia
Ouachita River

500 and 750 feet above sea level. If we take the lowlands we have an elevation of 500 feet about Fort Smith, and of 250 to 300 feet about Little Rock. The fall of the Arkansas river from Fort Smith to Little Rock, a distance of 140 miles on a line, is about 200 feet. A reversal of the drainage of the main stream from Little Rock to Fort Smith only with the same slope, would require an elevation of 400 feet at Little Rock. Or the reversal of the drainage from the Mississippi river to the Permian border, 100 miles west of Fort Smith, would require an elevation of 925 feet at the Mississippi river. And it is interesting to note that if the Mississippi region about Memphis and Helena were brought up to a level with the base of the Permian in Indian Territory it would be about on a level with the Carboniferous of southern Illinois, Indiana, western Kentucky, Tennessee and Alabama. This does not take into account the removal of Carboniferous rocks by erosion.

Drainage of the Ouachita uplift.—An examination of the accompanying map shows that the drainage of the Ouachita mountain region is now only partially controlled by the structure, and, as the tendency is for the structure to control it more and more, it is fair to assume that not long ago it was less influenced by the structure than it is at present. The present elevation of some of the Tertiary beds near the Silurian area lead me to believe that during Tertiary times nearly all the lower portion of the Ouachita uplift region was covered by water and sediments. This would account for the drainage, but inasmuch as there is a general southeastern direction to the streams (the Ouachita, the Saline, and the Caddo), the slope of the Tertiary surface as it emerged must have been toward the southeast—in the direction of the principal axis of disturbance. This will be the more apparent if it be remembered that the Silurian rocks across which the several forks of the Saline, the Ouachita and the Caddo flow, are largely novaculites—extremely hard and resisting rocks which stand out in high, almost perpendicular ridges.

Faults in Arkansas and Indian Territory.—The faults and folds across the eastern end of the Boston Mountains and close to the depressed area are approximately parallel to the Cretaceous and Tertiary margin. This margin has a direction of North 30° to 35° East. The folds through the Arkansas valley are approximately east-west, but about the eastern end of the Boston mountains they swing away toward the north, where they bear North 50° East.*

It was hoped that the faults in the State of Arkansas might throw much light upon the subsidence under consideration.

* Newsom and Branner, Amer. Geol., July, 1897, xx, pp. 1–13.

Thus far, however, the facts gathered regarding them are not sufficient in number, or they are not as yet well enough understood, to lead to any decided conclusions. In the northern part of the state, in the Boston Mountains region, the faults are nearly all normal or tension faults, while south of the Arkansas river and in the Ouachita region they are reversed faults. The one that lies nearest the Cretaceous border is the Red River monoclinal fold which merges into a fault about its northern end in the vicinity of Batesville. Here the downthrow is on the southeast side and the displacement is 165 feet;* at one place it is more than 200 feet. In Stone county a fault on Roasting-ear Creek has its downthrow of 100 feet on the south; in Baxter county on Spring Creek is a downthrow of between 200 and 300 feet on the south; on Rush Creek, Marion county, the downthrow is 260 feet on the south side; a fault about twelve miles long runs northeast from near St. Joe having a downthrow of about 200 feet on the south side. The St. Joe fault has its downthrow of 283 feet on the south. On Big Buffalo Creek (16 N., 22 W., secs. 10–11) the downthrow on the south is 400 feet. Many other similar cases might be cited. It should be added, however, that there are several faults in this same region having the downthrow on the north side; and there are some cases of long narrow strips having sunk downward. The faults here mentioned are north of the Boston mountains. South of the mountains we have the Red River monocline turning westward and passing into a great fault along the south face of the Boston mountains with a downthrow of several hundred—perhaps a thousand—feet on the south.

On the south side of the Arkansas Valley faults are known with the downthrow on the north, but on this side of the valley the faults are, in every case with which I am acquainted, reversed faults. Three miles up the river from Little Rock, at Big Eddy, are evidences of a reversed fault having the north side underthrust.

In the novaculite area through the Ouachita region but few faults have been located with certainty; the one mentioned by Mr. Griswold in his report on novaculites has no reference to the direction of the downthrow,† but the field-notes show that it is on the south side. The novaculite region as a whole has the beds pretty closely squeezed, and it is quite probable that instead of a few large faults it has a great many small ones.

Dr. N. F. Drake, who has lately studied the geology of the Indian Territory, tells me that the rule for Arkansas faults

* Ann. Rep Geol. Sur. Arkansas, 1890, vol. i, 111, 220.
† Ann. Rep. Geol. Sur. Arkansas, 1890, iii, 295.

holds in the Territory, namely, that the faults about the Ozarks are normal, while in the region south of the Canadian river they are reversed.

Faults in Texas.—I know of no considerable faults in the Cretaceous rocks of Arkansas, but in Texas there is a remarkable one. As a prominent break it begins about eight miles north of Austin and passes southward through the western edge of the city of Austin, through San Marcos, New Braunfels and San Antonio, and thence westward toward the Rio Grande. West and north of this fault rises an escarpment capped by Lower Cretaceous rocks, while on its east and south side the beds forming the top of the downthrow are Upper Cretaceous. This downthrow is from a thousand to fifteen hundred feet and is on the south side.* The nature of the contact between the upthrow and the downthrow often shows that the fault is not a single slip but several faults close together. The direction of this great Texas fault agrees closely with the western margin of the Cretaceous-Tertiary border through Arkansas. It is supposed to be of Tertiary or later age.†

The effect of such a depression upon the physiography of the lower Mississippi will be realized when we remember that such a movement (1500′) at the present time would submerge the greater part of the Appalachian mountains.

This fault shows, moreover, that there has been more than one epoch of disturbance and depression in the region under discussion. The embayment began in early Cretaceous times, but this fault is post-Cretaceous.

Faults in Alabama.—In the Cahaba coal fields of Alabama the faults are parallel with the Appalachian axis and the downthrow is on the northwest—the embayment side.‡ Inasmuch as the Coal Measures rocks abut against Silurian and Cambrian beds on the southeast, the total displacement cannot be determined. From the bottom of the Carboniferous on the northwest side to the surface on the southeast side is a distance of 5500 to 5600 feet, but this makes no allowance for erosion from the uplifted surface, which must be somewhat greater than the thickness of the Carboniferous beds. McCalley says that the throw of some of these faults is 10,000 feet or more.§ Sections across Blount Mountain, Alabama, coal field show the basin tipped toward the northwest.‖ In the Coosa coal field

* Communicated by N. F. Drake.

† R. S. Tarr, Proc. Acad. Nat. Sci. Phil., 1893, p. 319. Professor Hill shows six faults on the Colorado river northeast of Austin. Amer. Geol., May, 1889, p. 7.

‡ Map of the Cahaba Coal Field, by Squire and McCalley, 1896.

§ Coal Measures of the Plateau Region of Alabama, 1891, p. 218.

‖ A. M. Gibson, Report on Blount Mountain, 1893, map.

the faulting is said to be "not less than 8000, probably 10,000 feet," and "the base of the adjacent Coal Measures must be at least 4000 feet below sea level!"* Gen. Gibson also notes that the throw of the Alabama faults is greater toward the south. If the theory of the continuity of this old land area into Texas is correct, the ridge must have bent westward in western Alabama.

Eruptives in Arkansas and Texas.—The distribution of the eruptive rocks of Arkansas and Texas follow close and parallel to the old Cretaceous-Tertiary shore line. The syenites near Little Rock and those of Saline county, Arkansas, are both just within the present Tertiary border, while the Magnet Cove eruptives in Hot Spring county are but two miles northwest of it. The age of these eruptives has never been definitely settled. In Pike county there is a dike of peridotite in Lower Cretaceous rock. The bauxites near Little Rock are interbedded with Tertiary sediments, and, believing, as I do, that the bauxites were formed at the time of the extrusion of the syenites I conclude that the syenites are of Tertiary age. In any case they lie near the old Tertiary shore line, and appear to offer corroborative evidence of faulting or other weakness along this line.

At Austin, Texas, are many eruptives of Upper Cretaceous age;† in Uvalde county, Texas, eruptives penetrate Lower Cretaceous rocks;‡ in Rockwall county east of Dallas is an isolated area of Tertiary igneous rocks. Hill and Dumble have pointed out the fact that there is a line of eruptives of post-Eocene age at no less than fifty places from east of Austin to the Rio Grande, and speak of them as being "along a line of weakness in the earth's crust which has apparently existed in this region."§ These facts suggest that the line of weakness referred to by Messrs. Hill and Dumble has been manifesting itself since Jurassic times and that its influence reached into Tertiary times.

Hot Springs.—The hot springs of Arkansas are a little northwest of the Tertiary border, and may be regarded, like the eruptives, as having some possible connection with the line of disturbance that extends across the state. Professor Hill mentions evidences of hot springs along the line of the great fault in southwest Texas.

Thickness of the Cretaceous and Tertiary sediments.—If the lapping of the Cretaceous and Tertiary sediments across the Coal Measures of eastern Arkansas and Louisiana was

* A. M. Gibson, Rep. upon the Coosa Coal Field, p. 86.
† R. T. Hill, Amer. Geol., 1890, vi, 291.
‡ A. Ossan, Jour. Geol., i, 341.
§ Proc. A. A. A. S., vol. xxxviii, 242, 243; this Journal, vol. cxxxvii, p. 288.

caused by a depression, the thickness of these sediments should afford some clew to the amount of that depression. The thickness of the Cretaceous beds in Arkansas is estimated at 3520 feet.* In Texas, near Austin, the Colorado river exposes 5210 feet of rock overlying the Paleozoic, while further south, the Comanche alone is said to be nearly 5000 feet thick.† The dip of the Tertiary beds of Arkansas suggests a possible thickness of more than 3000 feet of Eocene alone in that state.‡

A bore hole put down on Orange Island, Louisiana, 130 miles due west of New Orleans, penetrated 2100 feet of salt and other sediments.§ The age of these salt beds is not known;‖ they may be either Cretaceous or Tertiary—more likely the former.

At Galveston, Texas, a deep well penetrates 3070 feet of sediments *without reaching the Eocene.*¶ These facts point to 3500 feet of Cretaceous, 3000 feet of Eocene and more than 3000 feet of sediments above the Eocene, in all over 9500 feet.

In western Alabama the Cretaceous beds are 2575 feet thick, while the Tertiary and post-Tertiary are 3120 feet—a total of 5705 feet deposited in that region since the Appalachian subsidence.**

Although more or less disconnected, these facts strongly suggest a total thickness of Cretaceous and post-Cretaceous sediments of somewhere between 5000 and 10,000 feet in that part of the embayment which the old Appalachian land is believed to have crossed. Such a depression would submerge the entire Appalachian system of to-day.

It cannot be positively stated, however, that this thickness extends over the entire lower Mississippi area, or even that it occurs at any one place. Indeed it is well known that there are Cretaceous outliers in Louisiana without any Tertiary beds on top of them.††

The "sunk lands."—The ancient earthquakes in northeast Arkansas and southeast Missouri were in the upper portion of this embayment. It is well known that at the time of these earthquakes large tracts of land sank and produced lakes, and

* R. T. Hill, Geol. Surv. Ark., Ann. Rep., 1888, ii, 188.

† R. T. Hill, Amer. Geol., May, 1889, iii, 289; this Journal, vol. cxxxiv, 301.

‡ Geol. Surv. Ark., Ann. Rep., 1892, ii, 186.

§ A. F. Lucas, Eng. and Mining Jour., Nov. 14, 1896, 464.

‖ Geology of Lower Louisiana and the salt deposit on Petite Anse Island, by E. W. Hilgard, Smithsonian Contributions to Knowledge, No. 248, Washington, 1872.

¶ Dumble and Harris, this Journal, July, 1893, vol. cxlvi, 39–42.

** E. A. Smith, The Coastal Plain of Alabama, p. 27. In the same volume Dr. Langdon gives a general section of 4215 feet, and the columnar sections (pl. 28, p. 728) give a maximum of 4175 feet of Cretaceous and Tertiary.

†† E W. Hilgard, this Journal, vol. cii, p. 395; Smithsonian Contributions No. 248, p. 27; Mineral Resources of the U. S. (1883), p. 557.

it is stated that the cracks in the earth ran northeast-southwest.* These disturbances were local, but occurring in a region which must necessarily have been more or less disturbed since Carboniferous times, they may safely be regarded as corroborative evidence.†

Submerged pre-Cambrian.—The Appalachian mountains, where they plunge southwestward beneath the Cretaceous sediments in central Alabama, are composed of Silurian, Cambrian and pre-Cambrian rocks (schists and granites), with Carboniferous beds lying against their northern side. In the area northwest of Austin, supposed to be the southwest terminus of these Appalachian beds, the rocks are Silurian, Cambrian and pre-Cambrian (schists and granites) with the Carboniferous sediments resting against their north side. These Texas beds plunge eastward beneath Cretaceous rocks. It is worthy of especial note that this Texas area was submerged during Cretaceous times,* and that it was formerly buried beneath Cretaceous sediments which have been removed by erosion. From this pre-Cambrian area the Cretaceous beds now extend away to the east, and it seems altogether probable that these beds conceal the eastward continuation of the older rocks. Naturally also the overlying rocks are thicker toward the east owing to the greater depression in that direction. Thus the rocks of the southwest end of the present Appalachians seem to be identical with those of the pre-Cambrian area of Texas, and to bear the same structural relations to the Carboniferous rocks on the one hand and to those of the Mississippi embayment on the other.

The structural relations of the Ouachita uplift.—I was at first disposed to think the Ouachita uplift a part of the old Appalachian land system, but this opinion I have been obliged to abandon. The theory here put forward and the facts that appear to support it throw much light on the structural and physiographic relations of the Ouachita anticline in Paleozoic times. Had this Ouachita anticline been an isolated one like the Ozark island, then the southward Carboniferous drainage would have flowed east of it very like the drainage of the present time. If it had been a part or end of the Appalachian system, the Carboniferous drainage would have flowed westward through the Arkansas valley, but we should be at a loss for an explanation of the phenomena of the Carboniferous area of central Texas, and also for the absence from the Ouachita region of the Cambrian and pre-Cambrian rocks so

* This Journal, vol. xv, 1829, p. 36.

† A second visit to the United States, by Sir Charles Lyell, N. Y., 1849, vol. ii, pp. 172–181; Bringier in this Journal, 1821, iii, 20–22; Flint in ibid., 1829, xv, 366–368.

‡ R. T. Hill, Bull. Geol. Soc. Am., ii, 527; this Journal, vol. cxxxvii, 283.

characteristic of Appalachian geology. But if the Ouachita uplift is the structural equivalent of the Cincinnati-Nashville anticline, then it was a region of shallow water at least, and during the land periods turned the drainage from the Indiana-Illinois basin westward through the Arkansas valley. This major anticlinal axis extended westward through the Arbuckle mountains of Indian Territory and ended with the Wichita mountains in southern Oklahoma Territory. The Appalachian system crossed the present Mississippi valley further south, and there was another broad syncline between that watershed and the Ouachita region, and the drainage flowed westward through this valley across south Arkansas, Louisiana and northern Texas, and entered the Carboniferous sea south of the Arkansas valley discharge.

That this last is the correct theory is borne out by the facts that follow:

Southern origin of the Ouachita sediments.—The Paleozoic sediments on the south side of the Ouachita uplift are coarser than the materials of the same beds on the north side. This peculiarity is noticeable even in the Silurian novaculites: those on the south "are pure in composition and massive, while on the north side they have largely the character of siliceous shales."* Again, the beds overlying the novaculites on the south are sandstones, while on the north they are shales. These facts seem to place the Ouachita uplift, in its relations to the source of its sediments, in a position analogous to that of the Cincinnati and Nashville arch whose sediments are supposed to have been derived from the Appalachian lands.

The Carboniferous sediments.—The accompanying map shows the varying thickness of the Carboniferous rocks. It is noticeable that the greatest thickness is in the Arkansas–Indian Territory valley, in central Texas, in western Pennsylvania, and in northwestern Alabama. Attention should be directed to the fact that only the upper part of the Texas Carboniferous beds is uncovered. On the Brazos River, southwest of Weatherford, *Fusilina* limestone is exposed, showing these beds to belong to the Upper Coal Measures. But these rocks are not the highest, but the lowest, exposed in the central part of the Texas Carboniferous area.† The Texas coal is therefore higher up than is the coal of Indian Territory and Arkansas. This shows that coal-forming conditions prevailed in Texas later than in Indian Territory and Arkansas. It cannot be said that the Arkansas basin shallowed earlier than that of Texas, for the Texas beds of equal age with the lowest coal of Arkansas are concealed by Cretaceous rocks.

* L. S. Griswold, Geol. Sur. Ark. Ann. Rep., 1890, iii, 193.
† Communicated by N. F. Drake.

These facts are all in keeping with the theory put forward. It is to be expected that the sediments would be thicker near the supplying land area, such as existed along the Appalachian highlands, and where the drainage became sluggish near the waters into which it is discharged, that is, in Texas, west Arkansas, and Indian Territory. And unless it be admitted that there was a land area across eastern Texas, Louisiana, and Mississippi, we are at a loss to explain the source of supply for the 5600 feet of upper Carboniferous sediments* in central Texas. In the Arkansas valley, where these sediments have been shown to have a thickness of 23,780 feet,† and in Indian Territory, where the Coal Measures are 25,000 feet thick, or with the Permian 26,500 feet (N. F. Drake), the supply of the coarser materials could hardly have come from elsewhere than the Ozark mountains in Missouri.

The central Texas coal area and the Indian Territory–Arkansas basin seem to represent the ends or mouths of synclinal valleys in which conditions favored the deposition of enormous beds of sandstones and shales. In the neck of Upper Coal Measures rocks near San Saba, Texas, where they almost abut against the pre-Silurian area, these beds strike about N. 35° E. This suggests a southeast origin for these sediments. In Arkansas and Indian Territory the upper beds strike across the trough of the valley in this fashion, while the lower ones are more nearly parallel with its sides. In the same way it is to be supposed that the earlier Coal Measures beds of the Texas trough swing round and strike east-west.

Marine Coal Measures fossils.—South of the Ouachita uplift the Coal Measures beds have yielded comparatively few fossils, and most of these are coal plants. A few crinoid stems and bryozoa, however, have been found near Antoine in Pike county (8 South, 23 West, sec. 24), enough to show that the conditions on the south side of the fold were very or quite like those on the north side. These conditions were: a low-lying region occasionally invaded by the sea. This idea is also borne out by the nature of the Carboniferous beds of central Texas, where limestones are interbedded with the usual sandstones and shales.‡

The Arkansas valley syncline sank occasionally during Coal Measures times so as to admit the sea across the region: this is shown by the marine fossils found in the rocks there.§ This

* R. S. Tarr (Amer. Geol., 1892, ix, 169) gives 8000 feet as the thickness of these rocks. Later work by N. F. Drake shows that earlier estimates are a little too high, probably because the dip is not so steep along the western edge of the Carboniferous. Fourth Ann. Rep Geol. Sur. Texas, 355–446.

† This Journal, 1896, vol. cli, p. 235.

‡ N. F. Drake, Rep. on the Colorado Coal Field of Texas, Fourth Ann. Rep. Geol. Surv. Tex., 355–446.

§ J. P. Smith, Proc. Am. Phil. Soc., vol. xxxv, No. 152.

sea lay along the eastern base of the Rocky Mountains, for while marine Coal Measures fossils are not common in the eastern part of the Coal Measures area, in Illinois and Arkansas they are much more plentiful, and in rocks of the same age along the foot of the Rocky Mountains they are still more abundant.

Résumé.

I. The Ouachita anticline is the structural equivalent of the Cincinnati-Nashville arch; this fold continues westward through the Arbuckle mountains in Indian Territory and to the Wichita mountains in southern Oklahoma Territory.

II. The Coal Measures drainage of the Illinois-Indiana-Kentucky basin flowed westward through the Arkansas valley into a Carboniferous mediterranean sea.

III. The drainage of the Coal Measures region south of the Ouachita anticline flowed westward and entered this sea north of the Texas pre-Cambrian area.

IV. The drainage of both the Arkansas and Texas Carboniferous areas was reversed about the end of Jurassic times, when orographic movements over southeast Arkansas, eastern Texas, Louisiana, and Mississippi submerged the former extension of the Appalachian watershed and admitted the early Cretaceous sea across the Paleozoic land as far north as southern Illinois.

V. This depression was not a deep one (Hilgard)* and did not all occur at one time, for there have been subsequent disturbances of a more or less similar nature in the same region.

VI. The evidences of these depressions are:

1. The reversed drainage of the Arkansas valley.
2. The reversed drainage over the Carboniferous area of central Texas.
3. The submerged eastern end of the Ouachita uplift.
4. The eastward slope of the peneplain of the Ouachita region.
5. The direction of the faults and folds near the eastern exposure of the Lower Coal Measures in Arkansas.
6. The great fault through Texas near the Tertiary border, having a downthrow of 1000 to 1500 feet on the south and east sides.
7. Eruptive rocks accompanying the Texas fault and the Tertiary border through that state and Arkansas to the Arkansas river.
8. Hot springs near the same line.
9. Faults in Alabama with a downthrow of 10,000 feet or more on the northwest side.
10. The thickness of the Cretaceous and Tertiary sediments over the depressed area: from 4,000 to 10,000 feet.

* This Journal, 1871, vol. cii, p. 394.

VII. The southwestern or central Texas end of the Appalachian land area was formerly covered by Cretaceous sediments, but it has since been uncovered by erosion; further east it is still concealed.

VIII. The Carboniferous beds uncovered in Texas all belong to the Upper Coal Measures; it is inferred that a greater thickness is still covered.

IX. The character of both the Silurian and Lower Coal Measures sediments of the Ouachita uplift show that they came from the south, so that the land area must have been in that direction during Paleozoic times.

X. The sea occasionally invaded both the Arkansas and Texas synclinal troughs during Coal Measures times, but coal-forming conditions obtained in the Texas syncline later than in the Arkansas basin.

XI. The Tertiary depression was probably more marked on the Arkansas than on the Tennessee side of the embayment; this is shown by the Cretaceous border being concealed by the Tertiary deposits in Arkansas, while in Tennessee, Mississippi and Alabama they are exposed in a broad belt.

Art. XL. — *The Combustion of Organic Substances in the Wet Way;* by I. K. Phelps.

[Contributions from the Kent Chemical Laboratory of Yale University—LXVI.]

In a former paper* I have shown that carbon dioxide may be estimated iodometrically with a fair degree of accuracy. Inasmuch as this method is not dependent upon the rate of flow or rapidity of generation of the carbon dioxide, it seemed possible that some advantage might follow its application to the determination of organic carbon, oxidized by liquid reagents.

Method of oxidation by Potassium Permanganate.

The first experimental test in this direction was made with oxalic acid, which was oxidized according to the well-known reaction of potassium permanganate in the presence of sulphuric acid. The apparatus used was the same as that previously described in the iodometric process, referred to above. It consisted, in the main, of an evolution flask and an absorption flask, properly connected. As an evolution flask, a wide-mouthed flask of about 75^{cm^3} capacity was used. This was closed by a doubly perforated rubber stopper, carrying a separating funnel for the introduction of liquid into the flask and a glass tube of $\cdot 7^{cm}$ internal diameter, which was expanded to a small bulb just above the stopper, to carry off the gas. This exit tube was joined by means of a rubber connector to a tube which passed through the rubber stopper of the absorption flask, which was an ordinary round-bottom flask of 250^{cm^3} capacity. This tube ended in a valve of the Kreider pattern,† which was enclosed in a larger tube, reaching nearly to the bottom of the absorption flask. The second hole of the stopper of this absorption flask, was filled by a glass tube closed by a rubber connector and screw pinch cock.

The barium hydroxide solution for use in the determination of the carbon dioxide was prepared by filtering a cold saturated solution of the commercial salt into a large bottle, which was connected with a self-feeding burette. The solution was standardized in the manner described in my former paper by boiling with an excess of decinormal iodine solution in an ether wash bottle. The short tube of the glass ground stopper of the bottle was sealed to a Will and Varrentrapp absorption apparatus, which was charged during the operation with a solution of potassium iodide to prevent the loss of elementary

* This Journal, vol. ii, p. 70.

† This Journal, l, p. 132.

iodine in the boiling; the long tube of the bottle was used as an inlet tube and was closed externally by a rubber cap during the boiling. After cooling, the excess of iodine used was determined by titration with decinormal arsenious acid solution and the iodine lost calculated on barium hydroxide molecule for molecule.

Potassium permanganate was prepared for use by dissolving the commercial salt in water, and boiling this solution, made acid with sulphuric acid, until free from carbon dioxide. Water was also prepared free from carbon dioxide by boiling distilled water until one-third had been driven off in steam and was kept until used in full-stoppered flasks.

For the first determinations of carbon, crystallized ammonium oxalate was weighed out and introduced into the boiling flask with 10–15$^{cm^3}$ of pure water and the flasks connected as described above with an appropriate amount of barium hydroxide solution (3–5$^{cm^3}$ in excess of the amount required to precipitate the carbon dioxide to be determined) in the absorption flask. The whole system was then evacuated with the water pump to a pressure of 200–225^{mm} and the oxalate solution in the boiling flask warmed. An excess of potassium permanganate solution was then run in through the funnel tube and the mixture warmed again, when the oxidation of the oxalate was shown by the carbon dioxide evolved. The carbon dioxide was completely set free by the introduction of 10$^{cm^3}$ of sulphuric acid (1:4) and was driven completely to the absorption flask by boiling for five minutes. During the passage of the gas into the absorption flask, it was shaken frequently and was kept cool by standing in a dish of water and by pouring cold water over it from time to time. If, during the boiling, any fears are entertained as to the strength of the vacuum in the flasks, they may be easily allayed by opening momentarily the stop cock of the funnel tube and noting the direction of the flow of water, contained in the funnel. After the boiling was ended, the atmospheric pressure was restored by allowing air, purified from carbon dioxide by passage through potash bulbs, to enter through the funnel tube of the boiling flask. Then the flasks were disconnected and the stopper of the absorption flask with its attachments was removed, the valve and its tube being carefully washed free from barium hydroxide. A second stopper, which was provided with a separating funnel, and a Will and Varrentrapp absorption apparatus, containing water to serve as a trap, was inserted into the mouth of the absorption flask and the emulsion brought to the boiling point. Decinormal iodine solution was then run in through the funnel tube in sufficient quantity to destroy the larger part of the excess of barium hydroxide and the emulsion brought to the

boiling point again, after which iodine was again run in but this time to the permanent red color of the excess of free iodine. After cooling, this excess of iodine was determined by titration with decinormal arsenious acid solution. Thus, the excess of barium hydroxide used being determined by the iodine lost, the barium hydroxide used, now in the form of carbonate, was known, from which the carbon dioxide which precipitated this carbonate, may be calculated.

The following results were obtained by this procedure.

TABLE I.

	Ammonium oxalate taken. grm.	BaO_2H_2 taken. grm.	BaO_2H_2 found. grm.	CO_2 found. grm.	CO_2 calculated. grm.	Error on CO_2. grm.
1.	0·2522	0·7267	0·1170	0·1565	0·1561	0·0004+
2.	0·2542	0·7267	0·1113	0·1579	0·1574	0·0005+
3.	0·5020	1·4535	0·2417	0·3110	0·3108	0·0002+
4.	0·5058	1·3954	0·1753	0·3131	0·3131	0·0000±
5.	1·0033	2·6163	0·1955	0·6213	0·6211	0·0002+
6.	1·0003	2·5951	0·1836	0·6189	0·6192	0·0003—
7.	1·0010	2·6163	0·2037	0·6192	0·6197	0·0005—

In experiments (5) and (6), a few drops of ammonia were added to the oxalate solution before running in the permanganate; in (3) and (7), the permanganate was treated to alkalinity with barium hydroxide; in the remaining experiments, (1), (2) and (4), the permanganate was slightly acid with the sulphuric acid used in its purification from carbon dioxide, as already described. The results obtained are good and it is plain that the oxidation proceeded regularly, whether the first action of the permanganate was in the alkaline or slightly acid solution.

Jones* has shown that formates may be determined volumetrically by titration with potassium permanganate in alkaline solution. In an attempt to determine formates by the process outlined above, the pure barium salt was used. This was prepared by treating the aqueous solution of formic acid with pure barium carbonate to neutrality and crystallizing the product. It was proven pure by ignition and weighing in the form of carbonate.

In making determinations of carbon in this formate, weighed portions were introduced into the boiling flask, together with sodium hydroxide solution, which was taken in such quantity as to more than neutralize the acid in the potassium permanganate. Naturally, the sodium hydroxide must be free from

* Amer. Chem. Jour., xvii, 539.

carbonate—which was effected by treatment with an excess of barium hydroxide and filtering. An excess of potassium permanganate is then run into the flask and the solution heated to boiling. An excess of dilute sulphuric acid is introduced into the mixture and the carbon dioxide, thus set free, completely driven over to the absorption flask and determined as before. Table II shows results obtained by the process.

TABLE II.

	Barium formate taken. grm.	BaO_2H_2 taken. grm.	BaO_2H_2 found. grm.	CO_2 found. grm.	CO_2 calculated. grm.	Error on CO_2. grm.
1.	0·5001	0·9302	0·1745	0·1939	0·1935	0·0004 +
2.	0·5033	0·9012	0·1402	0·1953	0·1947	0·0006 +
3.	1·0002	1·6861	0·1793	0·3867	0·3870	0·0003 —
4.	1·0059	1·6279	0·1093	0·3897	0·3892	0·0005 +
5.	1·3750	2·2529	0·1820	0·5315	0·5320	0·0005 —
6.	1·5028	2·4419	0·1754	0·5816	0·5814	0·0002 +

These results show plainly that the carbon of formic acid may be determined accurately by the method outlined.

It was found incidentally that ammonia cannot take the place of the sodium hydroxide in this process, probably because the ammonia volatilizes to the absorption flask during the boiling and is acted on by the iodine subsequently used and is thus registered as barium hydroxide.

It is a well-known fact that tartrates are oxidized by permanganates. I have found, however, that when tartaric acid is treated under the conditions of analysis outlined above in acid solution, the oxidation is incomplete; but that oxidation is complete if the tartrate is heated in a solution alkaline with sodium hydroxide and then acidified with sulphuric acid.

The tartrate used was a recrystallized tartar emetic, dried at 100° C. The following results were obtained with such a tartrate by this process.

TABLE III.

	Tartar emetic taken. grm.	BaO_2H_2 taken. grm.	BaO_2H_2 found. grm.	CO_2 found. grm.	CO_2 calculated. grm.	Error on CO_2. grm.
1.	0·5051	1·2450	0·1709	0·2756	0·2751	0·0005 +
2.	0·5030	1·2226	0·1536	0·2743	0·2739	0·0004 +
3.	0·7509	1·7355	0·1461	0·4094	0·4091	0·0003 +
4.	0·7541	1·7430	0·1410	0·4111	0·4107	0·0004 +
5.	1·0018	2·3456	0·2187	0·5458	0·5456	0·0002 +
6.	1·0005	2·2435	0·1196	0·5451	0·5450	0·0001 +

It seems possible to draw the general conclusion from the results recorded that organic substances which are oxidized completely by the permanganate may be determined by the process outlined above. It will also be seen that the use of the rubber stopper in the boiling flask, with due care to prevent its contact with the solution, does not introduce an appreciable error.

Wanklyn and Cooper* and others have noted the fact that potassium permanganate, whether in acid or alkaline solution, will not oxidize all organic substances (acetates, for example), even at the boiling temperature. It is well known that a mixture of concentrated sulphuric and chromic acids has a much wider field of action in oxidizing organic compounds than the permanganate. With hopes of applying this reagent more widely to the determination of organic carbon, the experiments about to be recorded were tried.

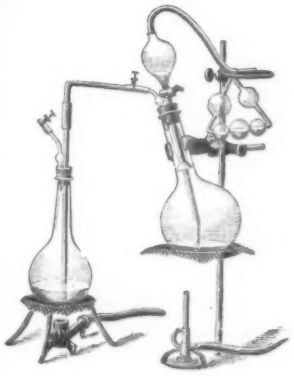
Method of Oxidation with Chromic Acid.

A concentrated mixture of chromic and sulphuric acids, although a much more powerful oxidizer than potassium permanganate in aqueous solutions, fails to oxidize completely many organic compounds. Thus Cross and Higgin† have shown that carbohydrates are among the number of organic substances; later Cross and Bevan find that carbohydrates and many other substances are oxidized completely to a mixture of carbon dioxide and monoxide. Messinger‡ has proven that carbon may be determined in organic compounds by passing the mixed products, resulting from the oxidation with chromic and sulphuric acids, through a short combustion tube, filled with granular copper oxide and heated in a furnace—all of which facts have been confirmed in my own experience.

Ludwig§ has observed that the contact of carbon monoxide with a mixture of chromic and sulphuric acids, especially when hot, results in the oxidation of that gas to carbon dioxide. This fact suggested the idea of substituting for the apparatus described above a new form, adapted to retain the first products of oxidation in prolonged contact with the oxidizing mixture. This apparatus, shown in the accompanying figure, by means of which, as the sequel shows, it has been found possible to extend the availability of the oxidizing mixture, is put together

* Phil. Mag. (5), vii, 138.
† Jour. Chem. Soc., 1882, 113.
‡ Ber., xxiii, 2756.
§ Am. Chem. Pharm., clxii, 47.

as follows: A thick walled, round bottom flask of a liter's capacity, serving as an oxidizing chamber, was closed by a rubber stopper with two perforations, through one of which passes the tube of a separating funnel of about 100$^{cm^3}$ capacity. The tube of this funnel reached nearly to the bottom of the flask and is drawn out at the lower end. A disc of platinum foil is hung in the neck of the flask, nearly closing it, and held in place by a platinum wire passing through the foil and tucked under the rubber stopper where the funnel tube enters. The second hole of the stopper is filled by the exit tube, a glass tube of 0·7^{cm} internal diameter. This tube is expanded just above the stopper to a small bulb which serves to prevent mechanical loss of the solid contents of the flask during the boiling. This tube is joined by means of a rubber connector (provided with a screw pinch cock) to the inlet tube of the absorption flask, which is an ordinary 500$^{cm^3}$ round bottom flask. This flask is also closed by a rubber stopper with two perforations, through one of which passes the inlet tube described above and through the other the exit tube, which is also enlarged to a small bulb just above the stopper and is closed by a rubber connector and screw pinch cock. The glass ground stopper of the funnel tube is carefully cleaned and lubricated with a thick solution of metaphosphoric acid.



Instead of getting the vacuum by the water pump, it may be gotten almost as quickly and certainly more simply by boiling water in the evolution flask and the barium hydroxide solution in the absorption flask at the same time—both flasks being connected ready for making a determination. When steam issues in good quantity from the exit tube of the absorption flask, the burner is removed from under the evolution flask and its screw pinch cock closed, and then the burner under the absorption flask and its screw pinch cock also quickly closed. The flasks are then allowed to cool.

In making a determination, the organic substance is weighed out in a counterbalanced bulb, so thin that it may be easily broken later and made with a wide mouth for convenience in introducing the solid substance. After the substance is weighed, the mouth of the bulb is sealed by heating in a small blow-pipe flame and the tube introduced into the evolu-

tion flask, together with an amount of pure potassium dichromate, which is known to be in excess of that required to oxidize the organic substance. The flasks are connected, as already described, with an appropriate amount of barium hydroxide solution in the absorption flask and 10^{cm^3} of pure water in the evolution flask and the vacuum obtained (as described above) by boiling both flasks, the boiling being stopped when the water in the evolution flask has decreased to 2 or 3^{cm^3}. Naturally, this boiling must be so regulated as not to allow loss of the solid material in either flask. The vacuum obtained, the tube containing the organic substance is broken by shaking the flask, and 20^{cm^3} of concentrated sulphuric acid, previously purified from organic material by heating to the fuming point with a few crystals of potassium dichromate, are run in through the funnel tube, when reduction of the chromic acid soon becomes evident. While still hot, the acid is shaken in the flask violently, the platinum foil hung in the neck serving to protect the rubber stopper. The flask is warmed to approximately 105° C., the highest temperature to which, as shown by Cross and Bevan,* a mixture of chromic and sulphuric acids may be safely heated without the disengagement of oxygen gas. Water is then run in until the crystals of chromic anhydride have disappeared and the danger of the evolution of oxygen is past. The solution is heated to its boiling point, care being taken that it shall not get under pressure, which can easily be observed by opening momentarily the stop-cock of the funnel tube and noting the direction of the flow of water, contained in the funnel. The flask is shaken and heated alternately for five minutes—a period of time which appears to be sufficient to bring about the oxidation of the small amount of carbon monoxide, originally produced. Then more water ($60–70^{cm^3}$) is introduced through the funnel and the stop-cock between the boiling and absorption flasks opened, when the carbon dioxide enters the absorption flask, which is kept cool and shaken as before. The contents of the evolution flask are then heated to boiling and a slow current of air, freed from carbon dioxide by passage through potash bulbs, allowed to enter through the funnel tube to keep the liquid from undue bumping. The boiling is continued for fifteen minutes, after which the excess of barium hydroxide is determined iodometrically and thus the carbon dioxide present estimated as before. Table IV shows results obtained by the treatment of crystallized ammonium oxalate and cane sugar, recrystallized from dilute alcoholic solution, in this manner.

* Jour. Chem. Soc., liii, 889.

TABLE IV.

	Substance taken. grm.	BaO_2H_2 taken. grm.	BaO_2H_2 found. grm.	CO_2 found. grm.	CO_2 calculated. grm.	Error on CO_2. grm.
			Analysis of ammonium oxalate.			
1.	0·5009	1·3534	0·1469	0·3097	0·3101	0·0004—
2.	0·5006	1·3400	0·1308	0·3103	0·3099	0·0004+
3.	0·5005	1·3400	0·1343	0·3094	0·3098	0 0004—
4.	1·0002	2·5460	0·1347	0·6188	0·6192	0·0004—
5.	1·0010	2·5192	0·1094	0·6185	0·6197	0·0012—
			Analysis of cane sugar.			
1.	0·2001	1·3926	0·1905	0·3085	0·3088	0·0003—
2.	0·2000	1·3926	0·1936	0·3077	0·3086	0·0009—
3.	0·2001	1·3926	0·1857	0·3097	0·3088	0·0009+
4.	0·2014	1·3400	0·1279	0·3111	0·3108	0·0003+

The results are evidently very satisfactory.

The Determination of the Oxygen required to Oxidize an Organic Substance.

Several different methods have been proposed for estimating the oxygen present in organic substances, depending, in general, upon the determination of the oxygen which must be supplied to burn the substance to a known amount of carbon dioxide and water—thus discovering by difference the oxygen originally contained in the substance. Lavoisier is said to have measured directly the oxygen used in burning organic substances; Gay-Lussac and Thénard determined the oxygen used by measuring the amount of potassium chlorate reduced by burning the organic compound; Baumhauer* determined the oxygen used by measuring the volume of oxygen entering the combustion furnace and subtracting the measure of the gas coming from the combustion tube, which was set up according to the well known method for determining carbon and hydrogen; Stromeyer† determined the amount of copper reduced by the ignition of the substance in copper oxide; Ladenburg‡ oxidized the substance by heating in a sealed tube with a known amount of iodic acid, determining at the end of the operation the amount of iodic acid left; Mitscherlich§ has estimated the oxygen in organic substances directly by decomposing the substance by ignition in a stream of chlorine gas, estimating the oxygen content by determining the resulting carbon dioxide and monoxide.

As it has been shown in the work described that carbon may be determined in organic substances by oxidation with chromic and sulphuric acids without the evolution of oxygen gas, it would seem that the determination of the oxygen in the sub-

* Ann. Chem. Pharm., xc, 228.
† Ann. Chem. Pharm., cxvii, 247.
‡ Ann. Chem. Pharm., cxxxv, 1.
§ Pogg. Ann., cxxx, 536.

stance might be effected by determining the amount of chromic acid used in the operation, taking into consideration the products of combustion. This can be readily accomplished by taking a weighed amount of pure potassium dichromate as the oxidizing agent and determining, at the end of the operation, the amount of chromic acid left by treatment of the residue with hydrochloric acid, absorption of the chlorine evolved in an alkaline arsenite of known strength and titration of the excess of that substance with decinormal iodine solution.

To test the accuracy of the determination of chromic acid under these conditions of analysis, weighed portions of pure fused potassium dichromate were introduced into a Voit flask, whose outlet tube was sealed to the inlet tube of a Drexel wash bottle, the outlet of which, in turn, was sealed to a Will and Varrentrapp absorption apparatus. An amount of hydrochloric acid, more than enough to completely reduce the chromate (15–40$^{cm^3}$ of the strongest acid), was added with 20$^{cm^3}$ of strong sulphuric acid and the total volume made up to 120–140$^{cm^3}$ of liquid. The sulphuric acid used here was purified from carbonaceous matter (as in the carbon determination above) by heating with a few crystals of potassium dichromate, the excess of which was reduced by holding the acid at a fuming point for about two hours, when a portion diluted with water gave no color with potassium iodide and starch paste. Pure arsenious oxide, in amount slightly in excess of that required to take up the oxygen to be given up by the chromate, was dissolved by the aid of heat in a solution of pure sodium hydroxide, taken in such quantity as to more than neutralize the arsenious acid and the hydrochloric acid used to reduce the chromate, and this solution was introduced into the Drexel wash bottle. The flask was then connected with the wash bottle, using a thick solution of metaphosphoric acid to lute the joint between the flask and its stopper. The absorption apparatus was charged with a dilute solution of sodium hydroxide. Carbon dioxide was generated in a Kipp generator by the action of hydrochloric acid on marble and purified from reducing matter by bubbling through a strong solution of iodine in potassium iodide and finally washed with a solution of potassium iodide alone. A slow stream of this purified carbon dioxide was allowed to enter the inlet tube of the Voit flask, the contents of which were then boiled. When a concentration to a volume of 30–40$^{cm^3}$ was reached, the boiling was discontinued and, after cooling and disconnecting the flask, the contents of the receiver were made acid with sulphuric acid and then alkaline with acid potassium carbonate, when the excess of arsenite was determined by titration with decinormal iodine solution. Sometimes during the reduction of the chromic acid, the red fumes of the chlorochromic anhydride volati-

lized to the receiver; but since the chromic acid thus produced is reduced later by the arsenite,* this transfer is of no account in the working of the process. The following results were thus obtained.

TABLE V.

	$K_2Cr_2O_7$ taken. grm.	As_2O_3 taken. grm.	As_2O_3 found. grm.	$K_2Cr_2O_7$ found. grm.	Error on $K_2Cr_2O_7$. grm.
1.	5·0002	5·1025	0·1144	4·9447	0·0555—
2.	5·0018	5·0799	0·0526	4·9849	0·0169—
3.	5·0005	5·0801	0·0582	4·9782	0·0223—
4.	5·0013	5·0706	0·0908	4·9365	0·0648—

The cause of the error shown in these experiments was traced finally to too great concentration of the sulphuric acid in the process. When the boiling begins the chromate is reduced gradually and if the evaporation of the water is pushed too rapidly, the sulphuric acid may reach a strength at which it begins to cause the reduction of the chromic acid with the evolution of oxygen instead of chlorine.

The obvious remedy is to conduct the boiling operation more slowly. It was found that, if from 5–6 hours time was taken for the proper concentration of the contents of the Voit flask, the presence of the sulphuric acid worked no harm, as will be seen from the following results. Experiments (1) and (5) were made with 5^{cm^3} of sulphuric acid present and the others with 20^{cm^3}, as used before.

TABLE VI.

	$K_2Cr_2O_7$ taken. grm.	As_2O_3 taken. grm.	As_2O_3 found. grm.	$K_2Cr_2O_7$ found. grm.	Error on $K_2Cr_2O_7$. grm.
1.	1·0004	1·0500	0·0398	1·0014	0·0014+
2.	1·0007	1·0531	0·0437	1·0006	0·0001—
3.	2·0013	2·0501	0·0299	2·0026	0·0013+
4.	2·0037	2·0727	0·0502	2·0049	0·0012+
5.	5·0020	5·1002	0·0495	5·0068	0·0048+
6.	5·0037	5·1018	0·0513	5·0066	0·0029+

In applying this method to the determination of oxygen used in the oxidation of an organic substance, the carbon determination was made as already described, the amount of water used being such as to leave $60–80^{cm^3}$ of liquid in the boiling flask after the carbon dioxide had been driven to the absorption flask by boiling. This liquid was then washed into the Voit flask and the chromic acid remaining determined by a second distillation (this time with hydrochloric acid) in the manner described above. In each of the experiments recorded

* Browning, this Journal, 1896, vol. i, 35.

below, 20$^{cm^3}$ of purified sulphuric acid were used in the carbon determination and 35$^{cm^3}$ of hydrochloric acid (sp. gr. 1·2) in the chromic acid determination. The ammonium oxalate used was the pure crystallized salt; the phthalic acid was recrystallized from its water solution and dried for a short time over sulphuric acid; the cane sugar was selected crystals of rock candy, recrystallized from dilute alcoholic solution and dried for a long time over sulphuric acid; the paper was ashless filter paper, dried to a constant weight over sulphuric acid; the tartar emetic was recrystallized from water solution and air dried; the barium formate was prepared by treating formic acid with an excess of pure barium carbonate, filtering hot and allowing the product to crystallize.

TABLE VII.

Substance taken. grm.	CO_2 found. grm.	Error on CO_2. grm.	$K_2Cr_2O_7$ taken. grm.	As_2O_3 taken. grm.	As_2O_3 found. grm.	Oxygen used. grm.	Oxygen required by theory. grm.	Error on Oxygen. grm.
				Analysis of ammonium oxalate.				
1. 1·0122	0·6265	0·0001—	2·0009	1·3002	0·0000	0·1160	0·1139	0·0021+
2. 1·0019	0·6212	0·0010+	2·0002	1·3517	0·0440	0·1147	0·1128	0·0019+
				Analysis of phthalic acid.				
1. 0·1002	0·2138	0·0014+	2·0012	1·2004	0·0814	0·1456	0·1448	0·0008+
2. 0·1093	0·2324	0·0007+	2·0000	1·1031	0·0634	0·1582	0·1580	0·0002+
				Analysis of cane sugar.				
1. 0·2025	0·3117	0·0008—	3·0000	1·7002	0·0796	0·2275	0·2273	0·0002+
2. 0·4012	0·6166	0·0024—	5·0000	2·3022	0·0366	0·4495	0·4502	0·0007—
				Analysis of paper.				
1. 0·3034	0·4932	0·0010—	3·5015	1·4017	0·0879	0·3589	0·3598	0·0005—
2. 0·4523	0·7334	0·0033—	5·0035	1·8000	0·0710	0·5368	0·5358	0·0010+
				Analysis of tartar emetic.				
1. 0·5057	0·2671	0·0009—	2·5018	1·7000	0·0766	0·1459	0·1462	0·0003—
2. 1·0099	0·5321	0·0030—	3·5003	1·7520	0·0198	0·2911	0·2919	0·0008—
				Analysis of barium formate.				
1. 1·0079	0·3906	0·0006+	3·0026	2·2002	0·0496	0·1423	0·1422	0·0001+
2. 1·5014	0·5814	0·0005+	3·0010	1·8080	0·0890	0·2118	0·2118	0·0000±

From these results, it will be seen that the process works with accuracy upon a great variety of organic substances. It was found impossible, however, to determine the elements in bodies which are at the same time volatile and hard to oxidize; for instance, ether oxidizes easily to acetic acid but difficultly beyond that stage; although the liquid acid is oxidized vigorously by chromic and sulphuric acids, the gaseous acid is hardly attacked at the temperature used; naphthaline was also found to be volatilized, and hence not attacked, to such an extent as to render its determination by this process valueless.

In conclusion, the author wishes to express his thanks to Prof. F. A. Gooch for many helpful suggestions.

Art. XLI.—*Some Features of Pre-Glacial Drainage in Michigan;* by E. H. Mudge.

To reach a definite and satisfactory conclusion in regard to the condition of the pre-glacial surface of a region now deeply covered with drift, is not an easy matter. The best, perhaps, that can be done is to examine the surface of an unglaciated region of like geologic age, and with the knowledge thus gained examine such data as may be obtainable from the covered region.

The lower peninsula of Michigan is such a covered area. In all the glaciated area of North America there is, I think, no region of equal extent, approximating 40,000 square miles, that is so deeply and uniformly covered with drift as this. Except within the southern half of the Carboniferous area, and in the vicinity of its southern rim, there are practically no outcrops in the interior of the state. The glacial mass seems to have concentrated itself upon this territory. Though the general direction of the glacial movement was southwest, that portion of the ice sheet which would naturally have passed over Wisconsin was largely deflected to the south by the valleys now occupied by Lakes Michigan and Huron, and joined with the great body which passed over Michigan,* mingling its volume of drift from the Lake Superior region with that derived more locally from the sedimentary terranes of the lower peninsula. The drift-mantle resulting from these conditions is so deep and so uniformly distributed that any conclusions in regard to the pre-glacial surface must be largely speculative, though we are not entirely without data bearing on the subject.

One thing seems certain. We are quite sure that during the several millions of years between the close of the Carboniferous and the beginning of the ice invasion the surface was exposed to the constant influence of the agents of denudation and erosion—rains, frosts, winds, chemical action and running streams. We conclude, therefore, that the condition of the surface just previous to the ice invasion was not very unlike that which may now be seen in unglaciated regions of similar age. The unglaciated region most suitable for comparison in this case is doubtless the driftless area of Wisconsin, above referred to. With this as a criterion, we may infer that our field was traversed by broad base-level valleys and sharp, ridge-like divides, the latter sometimes cut through by the

* "Driftless Area of Wisconsin," T. C. Chamberlin, Sixth Ann. Report U. S. Geol. Survey.

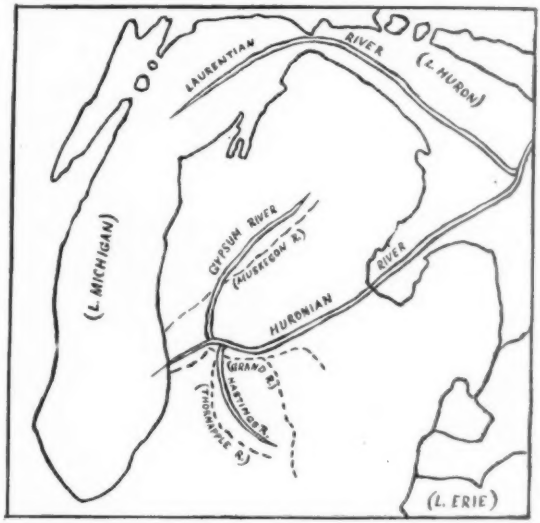
headwaters of streams, leaving detached erosion blocks, which in some cases had become reduced to fragile erosion towers, ready to tumble to decay. The more level surface was covered with disintegrated rock, not yet borne away. There were no lakes or marshes; these, if any there ever were, having been drained by the cutting down of their outlets. If, however, we would determine the location of the old streams, and join them into a consistent drainage system, we must depend upon such knowledge as an examination of the territory itself may yield us. This is not inconsiderable, though quite fragmentary and indefinite.

Notwithstanding the vigorous glacial action to which the lower peninsula was subjected, the more prominent features of the old topography do not appear to have been entirely obliterated. The greater valleys were not entirely filled, nor were the greater eminences smoothly planed down. The leveling process was left incomplete. Of the old valleys thus left in recognizable shape, that which crosses the state from east to west, and which is now occupied in part by the Saginaw river and its branches, and in part by the Grand and Maple rivers, is the most clearly discernible. It is still a striking topographic feature, and during the departure of the ice sheet it was for a long period the natural outlet of the great glacial lakes farther to the east. The theory that this valley is the modern representative of a far greater pre-glacial valley is by no means new, the same having been set forth especially by Dr. J. W. Spencer.* The evidence on this point is clear. It may be inferred from the great lateral extent of the depression, indicating that it is not of post-glacial origin, and it is clearly proven by a deep boring at Alma, which penetrated about 500 feet of drift and failed to reach the rock surface. There is reason to believe that the axis of the ancient valley was somewhat farther north than the center of the modern depression. The Alma boring is well to the north, while at one point in the bottom of the present river valley near Ionia the rocks come to the surface and project several feet above the river.† Two recent borings at Ionia, near the valley margin, found rock at moderate depths. This would indicate that the modern valley is located over the southern edge of the ancient one, the northern portion having been more completely filled by the flood of glacial debris which was swept into it from that direction. I have, therefore, on the accompanying map, located the ancient river somewhat to the north of the modern streams.

* Quar. Jour. Geol. Soc., November, 1890.

† See the writer's paper in this Journal for November, 1895.

In the same manner two other lesser ancient valleys may be postulated with some confidence. The first of these is represented by the valley of the Thornapple river, which enters the Grand a few miles east of the city of Grand Rapids. The depression occupied by this stream and its branches is rather broad and flat, and within its area there is a large number of small lakes. It is therefore not a product of post-glacial erosion. Borings at Hastings and at other points near the river passed through more than 100 feet of drift without finding rock. That this valley is also a remnant of an older one is a legitimate inference.



The second ancient valley referred to is buried beneath the valley of the modern Muskegon River. This stream rises in the highlands of the north central part of the peninsula, and flows directly southwest, reaching Lake Michigan only a few miles north of the mouth of Grand River. Its drainage area is peculiar, having a length of about 125 miles, while its lateral extent averages about 25 miles, and at some points is much narrower. That this elongated area is the modern representative of a pre-glacial valley is not claimed with so great confidence as in the case just described, though there is good reason for accepting this hypothesis. It will be noted, in the first place, that there is a large area, tapped by this supposed valley, which must have had a drainage system of some sort. When the central part of the peninsula was a great Carboniferous

swamp, the older and higher land adjoining must naturally have drained into it. Later, when the Huronian River dissected the Carboniferous strata, the drainage from the north must have gathered into a prominent stream at some point and become a branch of the main river. This important branch valley is, in my judgment, represented by the modern Muskegon Valley. Throughout much of the upper part of its course the surface of the valley rises rapidly on either side of its center, attaining an elevation of from 300 to 600 feet within a limit of five or six miles on either side. The limits of the valley may indeed have been determined by the presence of moraines, pushed up from either side by the Saginaw and Michigan glacial lobes, but much of the country is new, and has never been carefully examined, and there are few borings and no rock exposures on which to base an opinion. In the absence of other data it may be proper to assume that the drift-sheet is thinner over the more elevated portions, as in the southern part of the State, in which case we can plainly see in the upper Muskegon Valley a remnant of an old erosion gorge. The general configuration is such as to indicate that this old valley joined the main valley near Grand Rapids,* though the modern river flows into Lake Michigan.

Dr. J. W. Spencer, who has given much study to the subject, supposes that this region drained to the east, which is undoubtedly correct. He has named the main stream across the peninsula the Huronian River, and considers it as a branch of his Laurentian River, which he supposes to have drained the upper part of the Lake Michigan basin. But the location of the two tributaries, occupying the valleys above described, I think has not before been suggested by anyone. I have therefore named the southern tributary the Hastings River, from the chief city within the modern valley, and the northern the Gypsum River, from its coincidence with the supposed strike of the gypsum or sub-Carboniferous strata. The drainage system as thus made out will be clearly understood by an inspection of the map.

Ionia, Mich.

* See the writer's paper on the "Drainage Systems of the Carboniferous Area,"—in American Geologist, for November, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the verification of Dalton's law for Solutions.*—It is well known that Van't Hoff in 1886 first drew attention to the fact that the equations representing the generalizations arrived at by Boyle, Gay Lussac and Avogadro in the case of gases, are equally applicable to dissolved substances if the osmotic pressure of the molecules dissolved be substituted for the gaseous pressure. Moreover he not only deduced these conclusions from thermodynamic considerations, thereby giving them increased validity, but he established a thermodynamic relation between the osmotic pressure of a dissolved substance and the molecular lowering of the vapor pressure, or that of the freezing point of the solution. Wildermann has now shown that the third gaseous law called the law of Dalton also holds good for dilute solutions. According to Dalton's law the total pressure of a gaseous mixture in a given space is equal to the sum of the partial pressures of the constituents. In a solution of two or more substances it means that the total osmotic pressure of two or more dissolved substances is the sum of the partial osmotic pressures of each of them. Hence from the connection between osmotic pressure and the depression of the freezing point it follows that the total freezing point depression is equal to the sum of the partial freezing point depressions of each of the dissolved substances. In his experiments the author employed the freezing point method on account of the readiness with which mixtures of substances can be examined by means of it. The direct experimental proof of the law consisted in verifying one of the thermodynamical generalizations with which it has been experimentally connected The thermometers used read, the one to 0·001° and the other to 0·01°. After the freezing point of the water itself had been determined, a certain quantity of a given non-electrolyte, urea for example, was dissolved in it and the freezing point again determined. The second non-electrolyte was then added and the total depression noted which was produced by both electrolytes. The substances used with the urea were resorcinol, cane sugar, dextrose and alcohol. The results are given in tabular form and show that the constant of depression obtained for the second electrolyte is in no way inferior to that obtained when it is dissolved by itself in water. This result proves that the depression produced by the first electrolyte was calculated under a correct assumption, i. e. that the freezing point depression produced by the first electrolyte is independent of the presence of other substances in the liquid.

In a second paper, Wildermann gives the results of experiments made to verify the constant of Van't Hoff for very dilute solutions. This constant, i. e., the molecular depression of the

freezing point—was verified for moderately dilute solutions by Van't Hoff himself by means of the equation

$$t = 0{\cdot}02T^2/w$$

in which T is the absolute temperature, and w the latent heat of fusion of the solvent. If Bunsen's value for w, 80 calories, be taken, the value of the constant v is 1·87, somewhat smaller than 1·878 obtained if 79·6 be taken. Preliminary experiments in 1894–5 gave for alcohol and cane sugar the value 1·84 when obtained with the 0·001° thermometer. Subsequently 1·89 was obtained for cane sugar and resorcinol, 1·87 for urea, 1·86 for milk sugar, 1·85 to 1·86 for dextrose and 1·84 to 1·87 for maltose. In the present investigation, cane-sugar, alcohol, urea, acetone, aniline, phenol, dextrose, resorcinol, maltose and milk sugar, were the substances used, the solutions were very dilute and the observations for temperature were made with 0·001° and 0·01° thermometers, the convergence temperature being both above and below the freezing temperature. The results, which are given in tabular form, show only small deviations from 1·87, the theoretical value. Hence the author concludes that Van't Hoff's thermodynamic equation receives abundant confirmation from the results obtained with dilute solutions, the evidence being even more satisfactory than is the case with most of the generalizations established on the thermodynamic basis.—*J. Chem. Soc.*, lxxi, pp. 743, 796, July, 1897. G. F. B.

2. *On the Spectrum of Silicon.*—If a silicate be fused on a platinum plate and a highly condensed spark be allowed to impinge upon it,* Arnaud de Gramont has shown that the spectrum of the spark shows the following lines of silicon: 6969·7 strong, 6342·2 very strong, 5978·9 somewhat strong, 5960·3 distinct, 5948·0 doubtful, 5060·0 and 5045·5 very strong, 4575·7 very feeble, 4568·9 somewhat distinct, 4553·7 distinct, 4131·3 and 4129·2 somewhat strong but diffuse. These wave lengths are the means of determinations not only with the spark and fused salts but also with the spark and silicon electrodes in very pure hydrogen. The most characteristic lines are 6969·7 and 6342·2 in the red and 5060·0 and 5045·5 in the green. The silicon lines last mentioned are much more intense than the adjacent lines of platinum and air. The spectrum obtained by this method is well shown with sodium silicate, not as well by the potassium salt. Both potassium and sodium silico-fluoride show it particularly well, but zinc silicate gives it very imperfectly. Natural silicates if pulverized and fused with sodium carbonate, soon show the pairs of lines in the red and in the green.—*C. R.*, cxxiv, 192–194, January, 1897. G. F. B.

3. *On the Spark Spectrum of Cyanogen.*—Several reasons have been offered for supposing cyanogen to have a real spectrum. (1) When nitrogen is present, this substance is actually formed in the arc; (2) without nitrogen, carbon itself does not give the

* This Journal, IV, iii, 150, February, 1897.

same spectrum; (3) cyanogen burns with a flame giving a banded spectrum assumed from the foregoing facts to be that of this gas, and (4) this spectrum can be photographed when a condensed spark is passed between electrodes of gold in an atmosphere of cyanogen. HARTLEY has examined this question and concludes that the facts which have been obtained solely from observations on this arc are insufficient to establish the existence of a definite cyanogen spectrum. While certain facts have appeared tending to support the view that the carbon spectrum ought to be given by the flame of burning cyanogen, on the other hand it has been shown that lines somewhat resembling the edges of the cyanogen bands are seen when moistened graphite electrodes in air have sparks passed between them; these lines being intensified if the water used in moistening contains ammonium, calcium or zinc chlorides, developing into bands which become stronger as the solution is made more concentrated. This is explained by the fact that all mineral acids contain ammonia, freshly made sulphurous acid being the only one free from it. Salts of calcium and zinc made with ordinary mineral acids therefore always contain ammonium salts. Consequently if the so-called cyanogen bands are really due to the nitrogen of the ammonia, the spectrum of the graphite electrodes will evidently exhibit the bands more strongly in proportion as the solution used is more concentrated. The following facts are instanced to show that the bands and lines observed are really due to cyanogen and not to carbon alone: (1) The lines on the edges of the bands in the spectrum of a cyanogen flame coincide exactly with those photographed from a potassium cyanide solution, when the spark is passed in an atmosphere of carbon dioxide or of cyanogen, or when this spark is passed between gold electrodes in cyanogen gas; (2) the cyanogen spectrum in the flame of burning cyanogen is accounted for because there is excess of the gas present; and while the temperature of the flame is exceedingly high the gas within it is not in contact with a solid substance, and hence the gaseous compound is heated only to incandescence and immediate decomposition does not occur.—*Proc. Roy. Soc.*, lx, 216–221, 1896. G. F. B.

4. *On the Electrolytic Solution and Deposition of Carbon.*—It has been noticed already that during the electrolysis of dilute sulphuric acid with carbon electrodes, carbon monoxide and dioxide appear at the anode along with oxygen. COEHN has observed that by suitably altering the concentration of the acid, the temperature and the current density, the electrolysis may be so conducted that practically the sole products at the anode are carbon dioxide and monoxide; the gaseous mixture on analysis giving 70 per cent. CO_2, about 30 per cent CO and one per cent. oxygen. If this operation be conducted at low temperatures, the anode disintegrates and particles of carbon remain suspended in the acid. At high temperatures, the carbon dissolves in the acid, giving a yellowish and finally a reddish brown solution. This

solution thus obtained may be electrolysed; and if a platinum electrode be employed, a deposit of carbon is obtained at first as a thin colored film and then as a deposit of graphite. The solution itself reduces Fehling's solution and probably contains carbohydrates. On making a cell by means of a lead peroxide plate and a carbon electrode, and on working under the conditions above mentioned, the carbon acts as the soluble electrode. The cell gave an electromotive force of 1·03 volts and yielded a constant current until the lead peroxide was exhausted.—*Chem. Centralbl.*, i, 985, 1896; *J. Chem. Soc.*, lxxii, ii, 241, June, 1897. G. F. B.

5. *On the conversion of Nitrites into Cyanides.*—On heating together sodium nitrite and sodium acetate, the mixture finally explodes. KERP has shown that if the mass be mixed with dry sodium carbonate before heating, it glows and becomes dark colored, evolving hydrogen cyanide. It is then found to contain sodium cyanide as follows:

$$CH_3.COONa + NaNO_2 = NaHCO_3 + NaCN + H_2O.$$

About 25 per cent of the theoretical yield is obtained. Sodium nitrite, heated with formate, gives only sodium carbonate; while with propionate it deflagrates and gives a small amount of cyanide. If sodium acetate or cream of tartar be heated with potassium nitrate a violent explosion occurs, cyanide and cyanate being produced. Nitrite is probably at first formed and this by its action on the acetate gives nitroso-acetate, giving hydrogen cyanide and hydrogen-sodium carbonate.—*Ber. Berl. Chem. Ges.*, xxx, 610-612, April 1897. G. F. B.

6. *Physics; the Student's Manual for the Study Room and Laboratory;* by LeRoy C. Cooley, Ph.D., Professor of Physics in Vassar College. 12mo, pp. 448. New York, 1897. (The American Book Company.)—This book combines very skillfully class room and laboratory instruction. The principles it treats of are clearly and accurately stated and it cannot fail to become a valuable addition to the existing text-books on elementary physics. G. F. B.

7. *Action at a distance.*—P. DRUDE in an extended article discusses the mystery of gravitation, and is led to the conclusion that, in order to discover its mode of action, we must seek it in some hitherto undiscovered property of the ether, and he quotes Maxwell's remark in an article on attraction in the Encyclopædia Britannica, "The answer to the question of how two bodies act upon each other lies in the incitement of investigation of the properties of the intervening medium." Hitherto we have recognized only one property of a vacuum, that of the propagation of light velocity. The author is hopeful that we shall discover other properties of the so-called ether, which will enable us to build up a system of units which will not depend upon the materials of which the earth is composed but which will be connected with the general properties of the ether. The mean free wave length of the ether atom might serve for the measure of length, for instance. The unit of time would then result from the velocity of light.—*Wied. Ann.*, No. 9, 1897, pp. 1–49. J. T.

8. *Electrical tension at the poles of an induction apparatus.*— The electromotive force necessary to produce a spark of a certain length has been variously stated by investigators. Heydweiller (Wied. Ann., 48, p. 313, 1893) calls in question Professor Elihu Thompson's statement that a striking distance of 80^{cm} requires a potential difference of about 500,000 volts, and thinks that this is a very great overstatement and that 100,000 volts would be nearer the truth. A. OBERBECK has begun an investigation of the subject and points out that the maximum rise of the curve of electromotive force in an induction coil produced by interrupting the primary circuit should be the starting point in an investigation of this subject. Oberbeck finds that a potential difference of 60,000 volts can produce under certain conditions a stream of sparks of more than 10^{cm} in length.

Experiments in the Jefferson Physical Laboratory with a storage battery of 10,000 cells connected to a Planté rheostatic machine lead the author of this note to conclude that Professor Thompson's estimate is nearer the truth than that of Heydweiller. — *Wied. Ann.*, No. 9, 1897, pp. 109–133. J. T.

9. *Investigation of the Lenard rays.* — TH. DES COUDRES describes a simple method of studying cathode rays in free air. He employs a small transformer for exciting the rarified tubes, the primary of which consists of only three turns of a band of copper, while the secondary consists of about sixty turns. The primary is excited by the discharge of a Leyden jar. The construction of suitable tubes with aluminum windows is fully described. The author concludes that cathode rays behave in the outer air precisely as they do in the rarified space inside the tubes.— *Wied. Ann.*, No. 9, 1897, pp. 134–144. J. T.

10. *Behavior of rarified gases in approximately closed metallic receptacles in a high frequency field.*—Faraday showed that no electricity could be perceived inside a metallic cage, the exterior of which was connected with the ground. H. EBERT and E. WIEDEMANN show that this conclusion is not correct when the space inside the cage is filled with a rarified gas, which is subjected to the oscillations of an electric field. They conclude that in order that an electric charge shall penetrate through the holes of a metallic net into a space surrounded by this net, it is necessary that a rarified gas should exist on both sides of the net. The lighted gas apparently conducts the energy into the inner space. — *Wied. Ann.*, No. 9, 1897, pp. 187–191. J. T.

11. *Cathode Rays.*—In a very important paper Professor J. J. THOMSON discusses the ether theory of the cathode rays and the electrified particle theory. The latter theory has the great advantage that it is definite and its consequences can be predicted, whereas the ether theory depends upon unobserved phenomena in a ether the existence of which is in doubt. Thomson shows by ingenious experiments that the cathode rays carry a charge of negative electricity, and that they are deflected by an electrostatic field. Since they are also deflected by a magnetic field, he

sees no escape from the conclusion that the cathode rays are charges of negative electricity carried by particles of matter. The question then arises, what are these particles—are they atoms, or molecules, of matter in a still finer state of subdivision? Thomson gives a series of measurements to determine these questions. It was found that the electrical carrier or molecule must be small compared with ordinary molecules. (1) The carriers are the same whatever the gas through which the discharge passes. (2) The mean free paths depend upon nothing but the density of the medium traversed by these rays. Thomson favors the view that the atoms of the different chemical elements are different aggregations of atoms of the same kind. In Prout's hypothesis the atoms of the different elements were hydrogen atoms; in this precise form the hypothesis is not tenable, but if we substitute for hydrogen some unknown primordial substance X, there is nothing known which is inconsistent with this hypothesis, which is one lately supported by Lockyer from study of stellar spectra. In the cathode rays we have matter in a new state, in which subdivision is carried very much further than in ordinary gaseous matter—this matter being the substance from which all chemical elements are built up. Thomson computes that if the coil he used were to go on working uninterruptedly night and day for a year, it would produce only about one three-millionth part of a gram of this primordial substance.—*Phil. Mag.*, October, 1897, pp. 293–316. J. T.

12. *Effect of Pressure on Wave Length.*—W. J. Humphreys has an important article upon the above subject in the October number of the Astrophysical Journal, giving the results of an investigation carried on at the Johns Hopkins Physical Laboratory. Some of the conclusions reached are as follows:

Increase of pressure causes all isolated lines to shift towards the red end of the spectrum, the shift being proportional to the total increase of pressure, but apparently independent of the temperature. Lines of bands (at least in certain cases) are not shifted but different series of lines of a given element are shifted to different extents, while similar lines of an element suffer equal displacement. The lines of substances having as solids the greatest coefficients of linear expansion have the greatest shifts.

II. Geology and Natural History.

1. *Recent publications of the U. S. Geological Survey.**—Monograph Volume XXVI, *The Flora of the Amboy Clays*, by John Strong Newberry; a posthumous work edited by Arthur Hollick, pp. 1–260, plates i–lviii, 1895. This volume, as is explained by the editor was almost completed in the autumn of 1890, and shortly before the author's death in 1892 the manuscript and plates were handed to the editor for completion. Few alterations are made in the original text, and where they are

* Not previously noticed. See list in this Journal, August, 1897, p. 155.

made the editor's initials indicate the fact. A review of Dr. Newberry's contributions to fossil botany is contributed by Prof. Hollick.

The following Bulletins have been issued :—

No. 87, *A synopsis of American Fossil Brachiopoda, including bibliography and synonymy*, by Charles Schuchert, pp. 1–464, 1897. The author recognizes 2053 known species of Brachiopods from the sediments of North and South America, 1922 of which are known from North America. The statistics of original description, geological range, geographical distribution and systematic classification, are fully expressed in carefully prepared lists. The biological development is discussed in a chapter by the author, and Prof. Charles E. Beecher contributes a special chapter on the morphology of the brachia. The author's exhaustive study of the chronological history of the Brachiopods confirms the law of the rapid differentiation of a type of organisms at its beginning, announced by Hyatt in 1883 from a study of Cephalopods, and elaborated in the case of Brachiopods by the present writer in 1895.

No. 138, *Artesian well prospects in the Atlantic coastal plain region*, by Nelson H. Darton, pp. 1–232, plates i–xix, 1896.

No. 140, *Report of progress of the Division of Hydrography for the calendar year 1895*, by Frederick H. Newell, pp. 1–356, 1896. This report opens with a brief discussion of instruments and methods employed in the division.

No. 144, *The moraines of the Missouri Coteau and their attendant deposits*, by James Edward Todd, pp. 1–71, plates i–xxi.

No. 145, *The Potomac formation in Virginia*, by Wm. M. Fontaine, pp. 1–149, plates i–ii, 1896.

No. 148, *Analysis of Rocks with a chapter on Analytic methods, Laboratory of the United States Geological Survey, 1880 to 1896*, by F. W. Clarke and W. F. Hillebrand, pp. 1–306, 1897. The experience and chemical skill of the authors have enabled them to make many important contributions to our knowledge of rock analysis. H. S. W.

2. *Alabama, Geological Survey*, Eugene A. Smith, State Geologist.—The following three Reports have been issued since our last article (this Journal, vol. iii, p. 350), viz :

Bulletin No. 5. Part I, *A preliminary report on the Mineral Resources of the Upper Gold Belt*, in the Counties of Cleburne, Randolph, Clay, Talladega, Elmore, Coosa and Tallapoosa, by Wm. M. Brewer, Assistant, pp. 1–106, with three plates. Part II, *Supplementary Notes on the most important varieties of the metamorphic or crystalline rocks of Alabama*, their composition, distribution, structure, and microscopic characters, by Eugene A. Smith, Geo. W. Hawes, J. M. Clements and A. H. Brooks, pp. 107–197, 1896.

Iron making in Alabama, by Wm. B. Phillips, pp. 1–164, 1896. This Report is issued as an authoritative handbook of all the conditions which surround the iron-making business in Alabama.

Report on the Valley Regions of Alabama (*Paleozoic strata*), by Henry McCalley, Assistant State Geologist, Part II, *On the Coosa Valley Region*, pp. 1–862, plates x–xxxv, figures 5–18.—The illustrations are chiefly of ore banks, mines and quarries of iron ores, bauxite and limestone.

3. *Canada, Geological Survey*, Geo. M. Dawson, Director.—The Annual Report (new series), vol. viii (publication number 617) is composed of the separate reports A, D, J, L, R, and S, for the year 1895. They have been issued previously in separate form and several have been already noticed in these pages.

A. (No. 582.) Summary Report of the Geological Survey Department for the year 1896, by the Director, pp. 1–154A.

D. (No. 601) Report on the country between Athabasca Lake and Churchill River, by J. Burr Tyrrell and D. B. Dowling, pp. 1–120D.

J. (No. 541) Report on the Geology of a portion of the Laurentian area lying to the north of the Island of Montreal, by Frank D. Adams, pp. 1–184J.

L. (No. 584) Report on Explorations in the Labrador Peninsula, along the East Main, Kokasoak, Hamilton, Manicuagan, and portions of other rivers, in 1892–93–94–95, by A. P. Low, pp. 1–387L.

R. (No. 616) Report of the Section of Chemistry and Mineralogy, by G. C. Hoffmann, pp. 1–59R.

S. (No. 602) Section of mineral statistics and mines, Annual Report for 1895, by E. D. Ingall, pp. 1–103S.

The maps accompanying the reports in this are, 597, Map of the country between Lake Attabasca and Churchill River, 590, Province of Quebec, geological maps of parts of Joliette, Argenteuil, Terrebonne and Montcalm Counties, and four maps (585, 586, 587 and 588) of the Labrador Peninsula. There are also 17 plates, pp. 998. Ottawa, 1897. H. S. W.

4. *Indiana, 21st Annual Report of Department of Geology and Natural Resources, 1896*, W. S. Blatchley, State Geologist, pp. 1–718, plates i–xxxix, and six lithograph maps. 1897.—Besides detailed reports on the geology of several counties the volume contains an elaborate report on the Bedford Oölitic limestone, by T. C. Hopkins and C. E. Siebenthal (pp. 289–427); a chapter on Indiana Caves and their fauna, and a Catalogue of the uncultivated ferns and fern allies (Pteridophyta) and the flowering plants (Spermatophyta) of Vigo County, Indiana, by W. S. Blatchley, the latter containing 853 entries, and several reports on economic resources of the state. H. S. W.

5. *Fossil Insects of the Cordaites shales of St. John, N. B.*—G. F. Matthew has given a description of what he believes to be a new fossil insect, *Geracus tubifer*, n. gen. et sp. (with long suctorial proboscis, but with no head distinct from thorax and no wings and no evidences of appendages) from the Cordaites beds. Whether the specimen be insect or not, the author has in connection with this description brought together figures and references to the original descriptions of the remarkable land fauna, already known from these beds.

The list comprises 2 land snails, 2 Crustacea (Saw Bugs?), 4 Arachnoida, 6 Myriapoda, 2 Insecta-Thysanura, and 8 Insecta-Palæodictyoptera. The specimens come from Plant Beds No. 2 of the Lower Cordaite shales of St. John and neighborhood, in New Brunswick; which are referred to Middle Devonian by Dawson, but by the author are called Silurian, although some of the insects are recognized as like forms found in the Coal Measures. —*Bull. Nat. Hist. Soc., N. B.*, vol. xv, pp. 49–60, figs. 1–4, pl. i–ii, 1897. H. S. W.

6. *Cape of Good Hope, 1st Annual Report of the Geological Commission, 1896*, J. X. Merriman, Chairman, pp. 1–52, Capetown, 1897.—This volume consists of a few brief reports of the first year's work in preparation of a geological map of the colony. The chief economic interest in the survey centers in seeking for coal beds and in determining the hydrographic conditions of the region. One of the reports by E. H. L. Schwartz, assistant geologist, gives details of the peculiar coal seam at Leeuw River's Poort, occurring in a fissure, the chief part of which cuts the Kooro beds nearly vertically. The mode of occurrence reminds one of the Albertite beds of Nova Scotia, and we would suggest that it may be of similar origin. H. S. W.

7. *Glacial observations in the Umanak district, Greenland;* by George H. Barton (Techn. Quart., vol. x, No. 2, pp. 213–244, 1897).—In this Report, B, of the scientific work of the Boston party on the sixth Peary Expedition to Greenland the author has given a vivid narrative, illustrated with numerous photographic reproductions, of the geological and physical features of the region about Umanak Fiord. H. S. W.

8. *Les Variations de longueur des Glaciers dans les Régions arctiques et boréales par* M. Charles Rabot. Première partie, Geneva, 1897 (Commission Internationale des Glaciers).—Following in the line of the classical work of Forel upon the glaciers of Switzerland, the author has investigated the glaciers of the extreme north, with respect to the variations in length which they have undergone during the past two hundred years. The countries most particularly considered are Iceland and Greenland.

In the case of Iceland, observations more or less accurate are available for comparison since the close of the 17th century. The author gives many interesting statements about each glacier, and in conclusion sums up the subject as follows: Since the colonization of Iceland by the Normans, the glaciers of the island have considerably increased, this being particularly marked on the southern slope of Vatnajökull, where a large extent of territory has been again covered by the ice. More in detail, he remarks that at the end of the 17th century and the commencement of the 18th, the glaciers were less extended than to-day; but about this epoch, a period of growth was entered upon, interrupted towards the middle of the 18th century in the case of a certain number of the streams by a rather ill-defined period of retreat; but after this, the majority of the glaciers had a remark-

able extension, producing a true invasion which continued during the larger part of the 19th century, and in the case of some streams has not yet been arrested. In the majority of cases, however, after this time of extension a period of diminution set in; this phase appearing to have commenced sooner in the north (1855–1860) than in the south (1880). This movement of retrogression, thus far at least, has not had an amplitude equal to the growth which immediately preceded it. The retreat of the Iceland glaciers presents neither the importance nor the generality of the great phase of diminution established in the Alps between 1850 and 1880. It has rather the character of a secondary phenomenon as compared with the great increase marking the end of the 18th and the larger part of the 19th centuries.

In the case of Greenland, the information is much less exact and minute; so that whatever conclusions are reached must have more or less of a hypothetical value. The author remarks that early authors, deceived by the name of the country, believed that it was truly a "green land" up to the 9th century at the time of the arrival of the first colonists; the idea being that the inland ice was of comparatively recent date. This, however, is a complete error. The earliest document available (13th century) gives a general description of the glaciers which is as accurate as a geologist could write to-day.

The unanimous testimony of the natives affirms that at several points of Danish Greenland, on the west coast up to 72° N. lat., the glaciers have moved forward since the historical period, and Commander Holm gives the weight of his authority to these accounts, at least for the southern portion of the country.

In any case, an increase appears to have been established about the commencement of this century, and to have continued up to the present time, in the greater part of Greenland.

In general, it may be said that particularly in the north the inland ice of Greenland seems at present to be stationary at its maximum point, while in the south a slight diminution manifests itself, but too slightly marked to arrest the progressive movement of the ice noted by Commander Holm. Certainly, during the middle of this century, there is no phase of retreat to be noted which can be compared in extent or duration to that in the Alps. On the contrary, during this period, at least on certain local glaciers, particularly of Disko and Upernavik, a progression has been noted. Observations on Jan Mayen (71° N. lat.) show that the glaciers of Beerenberg have progressed since the end of the 17th century, as is true of a majority of those of Iceland.

9. *Esquisses Sélénogiques*, II, par W. Prinz (from *Ciel et Terre*, xviii).—The author has carried on an extended and interesting series of studies in regard to the surface features of the moon, and in this, his second paper, he mentions some of the more prominent of them, particularly with reference to their similarity to certain analogous features of the earth. For example, he discusses in detail, with a number of figures, the craters of the

Hawaiian Islands, also those of Java, Iceland, etc.; further the volcanic troughs of East Africa. The resemblance brought out in certain salient peculiarities is very striking, and it is rightly urged that a comparative study of the lunar and terrestrial surfaces in these and similar directions is likely to lead to a much better knowledge of the moon's history and a safer interpretation of what the telescope reveals.

10. *Experimental Morphology;* by C. B. DAVENPORT, Ph.D. Part First, Effect of chemical and physical agents upon protoplasm. New York, 1897 (The Macmillan Company).—The thoroughness which characterizes this important treatise renders it the most useful annotated bibliography of the subject which has appeared. But it is far more than an expanded bibliography. With a good sense of proportion, Dr. Davenport has placed at the command of biologists, not merely the results which have already been secured in this fascinating field, but he has pointed out certain directions which new investigations ought to pursue if they are to be fruitful. The sequence of subjects does not commend itself to us as in all respects the best, for it appears as if the effect of molar agents and of varying moisture upon protoplasm might well precede instead of follow the action of chemical agents and the molecular forces, but, aside from this, one can go with the author along a straight path, until he comes to the end of this part, now before us, namely, the action of light and heat upon protoplasm.

The general considerations on the effects of chemical and physical agents upon protoplasm, which constitute the closing chapter of this part, are carefully stated, and keep on relatively safe ground: they are at the same time of a distinctly suggestive character which must aid in carrying out the chief wish of the author, namely, the stimulation of further inquiries in this attractive and fertile field. Botanists owe to Dr. Davenport very sincere thanks for the exhaustive manner in which he has presented the botanical side of his subject. G. L. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Geological Lectures of Harvard University.*—Dr. HANS REUSCH, Director of the Geological Survey of Norway, has been appointed to the Sturgis-Hooper Professorship of Geology in Harvard University, left vacant since the death of Professor J. D. Whitney, a year ago. Dr. Reusch will deliver two courses of lectures. During the first half year he will treat of Vulcanism: volcanoes and eruptive rocks in general; earthquakes and movements of the earth's crust. In the second half year, he will consider the Geology of Northern Europe, and its relations to general geology. These lectures will be given in the Museum, where the Whitney geological library will be immediately accessible. The third hour of each week will be set apart for seminary work, with reports and discussions on geological literature. In the spring,

Dr. Reusch proposes to take part in instruction of advanced students in the field.

2. *The Calculus for Engineers;* by JOHN PERRY, F.R.S., Professor of Mechanics and Mathematics in the Royal College of Science; pp. 378. London and New York, 1897 (Edward Arnold).—This is a work written with much freshness and even, it may be said, vivacity. Every step is illustrated by a profusion of applications to problems of engineering, and the question which the academic beginner in Calculus is so often constrained to ask "what is it all good for" would never suggest itself in reading this text-book. Without sacrificing anything of thoroughness the book is remarkably free from the abstruseness which is so blinding to all but the born mathematician and seems much better fitted than the usual text-book to make the Calculus real to all classes of students as well as engineers. W. B.

3. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipzig (Wilhelm Engelmann).—The latest additions in the department of physics to this excellent library of scientific classics are numbers 81, 86 and 87. These give respectively Series I and II (1832), Series III to V (1833) and Series VI–VIII (1834) of Faraday's Experimental investigations of Electricity (Experimental-Untersuchungen über Elektricitat).

Grundprobleme der Naturwissenschaft: Briefe einer modernen Naturforscher von Dr. ADOLF WAGNER, pp. 1–255, Berlin, 1897.

OBITUARY.

VICTOR MEYER died on the 8th of August, 1897, in the 49th year of his age. After studying chemistry with Bunsen at Heidelburg and with Baeyer in Berlin, he was called in 1872 to the Zürich Polytechnic, from which place he went in 1885 to Göttingen and in 1889 to Heidelberg, on the retirement of Bunsen. As an investigator, whether in the field of physical or organic chemistry or as an experimentalist, he stood in the first rank. His investigations on the nitro-paraffins in 1872 and on the isonitroso compounds in 1882, his discovery of the two isomeric benzil di-oximes in 1888, which laid the foundation of our knowledge of the stereochemistry of nitrogen, as well as his discovery of thiophene with its numerous derivatives in 1882, may serve as examples of his organic work. His air-displacement method of determining vapor density, devised in 1878, was one of the most ingenious and valuable methods ever given to chemistry. His "Lehrbuch der Organischen Chemie," written in 1891, in connection with Jacobson, is in many respects the most valuable treatise on the subject. The later years of his life were clouded by ill health, but he continued his intense activity without the rest he needed. This brought on insomnia and led to his early death. Though he had accomplished so many and so brilliant achievements in his favorite science, still greater things were promised in his future. His loss to chemistry is well nigh irreparable.

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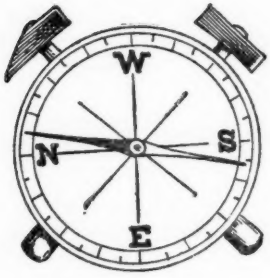

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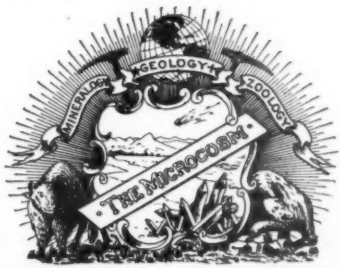

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(1) Described in this Journal Sept., 1895. (2) Ibid Nov., 1887. (3) Proc. Roch. Acad. Sci. Vol. I. (4) This Journal Aug., 1888. (5) Ibid July, 1893. (6) Ibid June, 1894.

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X.

METALLIC CLASSIFICATION OF MINERALS.

Showing the Various Combinations in Which the Metals Occur in Nature.

Under each metal, with its salts as sub-headings, are mentioned the mineral species in which it is a constituent. Several elements which are acidic in character, but commercially important, are included.

The common metals, Aluminium, Calcium, Copper, Iron, Lead, Magnesium, Manganese, Potassium, and Sodium; (also Phosphorus,) are found in a great number and variety of minerals. In this list, species containing less than ten per cent. of one of these metals do not appear under its heading, although they may appear under other metals. Varieties and doubtful species are not enumerated under the common metals.

Under the less commonly occurring metals are given all minerals containing five per cent.; under the rare or precious metals, a fraction of one per cent.

Minerals containing but one basic element are printed in *italics*. They are given first position following the sub-headings, and are arranged in order of the per cent. of metal they carry. Here are included Sulphantimonides, etc.; Niobates, Tantalates; Phosphates, Arsenates, etc., etc., in which Antimony, etc., are acidic. Under the heavy type headings of these elements will also be found again those minerals into which they enter.

Under these acidic sub-headings, *e. g.*, "Arsenates of Metals," minerals having but the one acid are printed in *italics*.

Minerals containing more than one basic element (or under acidic headings more than one acid), are printed in ordinary brevier, following the simpler compounds in italics, and are arranged in order of the per cent. of metal (or acid) contained. The names of complex compounds are repeated under the headings of the various elements contained.

Aluminium (Al) 27.

Minerals containing less than 10% pure Aluminium are omitted.

Arsenate. Durangite, Liskeardite.
Borate. *Jeremejevite*, Rhodizite.
Carbonate. Dawsonite.
Double Salts. *Topaz*, Svanbergite, Amblygonite, Sodalite, Lepidolite, Ardennite, Zinnwaldite, Cirrolite, Hamlinite.
Fluoride. *Fluellite*, Ralstonite, Prosopite, Chiolite, Gearksutite, Thomsenolite, Cryolite, Pachnolite.
Oxide. *Corundum, Diaspore, Bauxite, Gibbsite*, Chrysoberyl, Spinel, Gahnite, Zincaluminite, Tavistockite, Hydrotalcite.
Phosphate. *Turquois, Sphærite, Peganite, Fischerite, Wardite, Evansite, Wavellite, Variscite, Callainite, Zepharovichite*, Goyazite, Lazulite, Plumbogummite, Eosphorite, Kehoeite, Childrenite.
Silicate. *Dumortierite, Andalusite, Sillimanite, Zunyite, Cyanite, Schrotterite, Collyrite, Allophane, Kaolinite, Halloysite, Newtonite, Pyrophyllite, Cimolite, Montmorillonite*, Sapphirine, Margarite, Staurolite, Kornerupine, Xanthophyllite, Rumpfite, Seybertite, Paragonite, Eucryptite, Zoisite, Muscovite, Anorthite, Meionite, Euclase, Tourmaline, Ottrelite, Hydronephelite, Nephelite, Iolite, Kaliophilite, Thomsonite, Carpholite, Labradorite, Microsommite, Gismondite, Wernerite, Cancrinite, Hauynite, Andesine, Spodumene, Natrolite, Lepidolite, Corundophylite, Gehlenite, Scolecite, Mesolite, Jadeite, Prehnite, Oligoclase, Leucite, Sarcolite, Analcite, Mizzonite, Hyalophane, Laumontite, Levynite, Daphnite, Anorthoclase, Garnet, Aphrosiderite, Prochlorite, Edingtonite, Gmelinite, Lawsonite, Chabazite, Phillipsite, Albite, Partschinite, Marialite, Orthoclase, Microcline, Beryl, Offrétite, Wellsite, Bliabergite, Caswellite, Hydrobucholzite.
Sulphate. *Felsobanyite, Alumian, Paraluminite, Aluminite, Alunogen*, Fuggerite, Alunite.

Antimony (Sb) 120.

Arsenide. *Allemontite*, Antimonial Arsenic.
Double Salts. *Kermesite*, Kylindrite.
Antimonates of Metals. *Romeite, Atopite, Bindheimite, Monimolite, Magnetostibian*, Manganostibiite, Lewisite, Nadorite, Melanostibian, Ochlorite, Långbanite.
Antimonides of Metals. *Breithauptite, Horsfordite, Dyscrasite*, Willyamite, Ullmannite, Corynite, Wolfachite.
Antimonites of Metals. Mauzeliite, Falkenhaynite.
Native. *Pure Antimony.*
Oxide. *Senarmontite, Valentinite, Cervantite, Stibiconite*, Chondrostibian, Basiliite.
Sulphide. *Stibnite*, Guejarite, Berthierite, Livingstonite, Chalcostibite, Zinkenite, Miargyrite, Plagionite, Warrenite, Stylotypite, Jamesonite, Brongniardite, Semseyite, Andorite, Famatinite, Diaphorite, Freieslebenite, Bournonite, Tetrahedrite, Boulangerite, Epiboulangerite, Pyrostilpnite, Pyrargyrite, Meneghinite, Geocronite, Stephanite, Kilbrickenite, Polybasite, Kobellite, Polyargyrite.

Arsenic (As) 74.9.

Arsenates of Metals. *Berzeliite, Haidingerite, Pharmacolite, Brandtite, Roselite, Scorodite, Carminite, Wapplerite, Caryinite, Forbesite, Trichalcite, Svabite, Cabrerite, Symplesite, Annabergite, Sjögrurfite, Chenevixite, Kottigite, Mixite, Uranospinite. Zeunerite, Trögerite, Atelestite, Walpurgite, Trippkeite*, Durangite, Picropharmacolite, Arseniopleite, Conichalcite, Mazapilite, Leucochalcite, Sarkinite, Pharmacosiderite, Olivenite, Adamite, Arseniosiderite, Adelite, Brandtite, Erinite, Lindackerite, Tilasite, Cornwallite, Euchroite, Chondrarsenite, Bayldonite, Lossenite, Hemafibrite, Flinkite, Pitticite, Clinocalcite, Liroconite, Tyrolite, Allactite, Synadelphite, Liskeardite, Hematolite, Mimetite, Chalcophyllite, Rhagite, Ecdemite, Veszelyite, Rhodarsenian.
Arsenides of Metals. *Skutterudite, Safflorite, Chloanthite, Rammelsbergite, Smaltite, Löllingite, Allemontite, Niccolite, Sperrylite, Domeykite, Algodonite, Whitneyite*, Cobaltite, Arsenopyrite, Glaucodot, Gersdorffite, Lorandite, Corynite, Wolfachite, Alloclasite, Rittingerite.
Native. *Pure Arsenic, Arsenolamprite.*
Oxide. *Arsenolite, Claudetite.*
Sulphide. *Realgar, Orpiment*, Binnite, Sartorite, Dufrenoysite, Enargite, Tennantite, Proustite, Guitermanite, Xanthoconite, Jordanite, Epigenite.

Barium (Ba) 137.

Carbonate. *Witherite*, Bromlite, Barytocalcite.
Double Salt. Cappelenite.
Nitrate. *Nitrobarite.*
Phosphate. Uranocircite.
Silicate. Edingtonite, Harmotome, Hyalotekite, Wellsite, Hyalophane, Brewsterite.
Sulphate. *Barite.*

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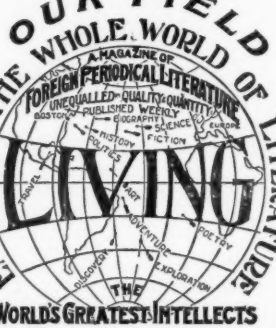

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